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ROSETTA: BEHIND THE SCENES AT MISSION CONTROL

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Welcome

The new year brings a new dawn: the age of totality is upon us

Have you got a wishlist of targets most in need of observation in 2015? Mine includes an exploration of the Moon and planets, particularly the area bordered by the Mare Imbrium, Serenatatis and Vaporum, and the opposition of Saturn in May. Turn to page 32 to discover what six of the most dedicated amateur astronomers from the UK and the US will be training their scopes on in the next 12 months: there could well be something to add to your list.

Doubtless many of will be looking forward to 20 March. This is the date of the Faroe Islands total solar eclipse, and we in the UK will be witnessing an impressive partial solar eclipse that calls for preparations to be made, in spite of the ever-present chance of cloud. This eclipse is the start of something of a purple patch in terms of total solar eclipses: our planet will be bestowed with totality for the next three years. On page 40, Elizabeth Pearson examines the causes of this boon, and on page 44 we catch up with a dedicated eclipse chaser, for whom this period is sure to be rather busy!

This issue sees something of a change to our *Skills* section: we say goodbye to Carol Lakomiak's monthly sketching column. I'm sure you will join me in thanking her for sharing the satisfaction of committing your observations to paper for the past five years. Filling her shoes is a tall order, so who better than 2014's Astronomy Photographer of the Year, James Woodend? He is the first contributor to our new monthly image processing column on page 85, giving us insight into how to create award-winning aurora imagery.

Enjoy the issue!

Chris Bramley Editor

PS Next issue goes on sale 22 January.

This month's contributors include...

MAGGIE ADERIN-POCOCK
SKY AT NIGHT PRESENTER

Relive the drama of Philae's descent to comet 67P with Maggie's report from ESA. *Page 21*

WILL GATER
ASTRONOMY AUTHOR

Will brings inspiration for the new year: watch lists from top amateurs, plus a selection of our picks for 2015. *Page 32*

ELIZABETH PEARSON
STAFF WRITER

If eclipses occur in regular seasons, why are total eclipses so rare? Elizabeth reveals all in our totality special. *Page 40*

JAMES WOODEND
APY 2014 WINNER

Champion astro imager James reveals his aurora processing secrets in our brand new column. *Page 85*

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NEW TO ASTRONOMY?
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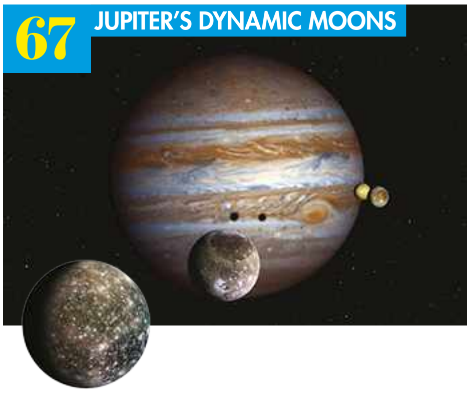

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BBC Sky at Night MAGAZINE

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Annual subscription rates (inc P&P): UK cheque/credit card £59.88; Europe & Eire Airmail £69; rest of world airmail £79. To order, call 0844 844 0260

ISSN 1745-9869

A descent into history

Follow the journey of the Philae lander as it left the safety of Rosetta and dived down towards its comet

On 12 November 2014, the pioneering scientists behind ESA's Rosetta mission captured the world's attention by landing the Philae probe on the surface of comet 67P/Churyumov–Gerasimenko. Not only was this the first time any man-made object had been landed on a comet, this incredible feat was controlled from a staggering distance of 500,000 million km away at ESA's Space Operations Centre in Darmstadt, Germany. We dedicate this *Eye on the Sky* to this defining moment in the history of spaceflight.

▲ Farewell Philae

ROSETTA SPACECRAFT, 12 NOVEMBER 2014

This image, taken by the Rosetta spacecraft's OSIRIS narrow-angle camera, captures the isolation of the Philae lander shortly after separation, as it made the slow 10km descent to the icy space rock below. The moment of separation marked the end of a joint journey that had lasted for more than 10 years and covered more than 6 billion km.

ESA/ROSETTA/MPS FOR OSIRIS TEAM MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA, ESA/ROSETTA/PHILAE/CIVA X 2

Touchdown! ▶

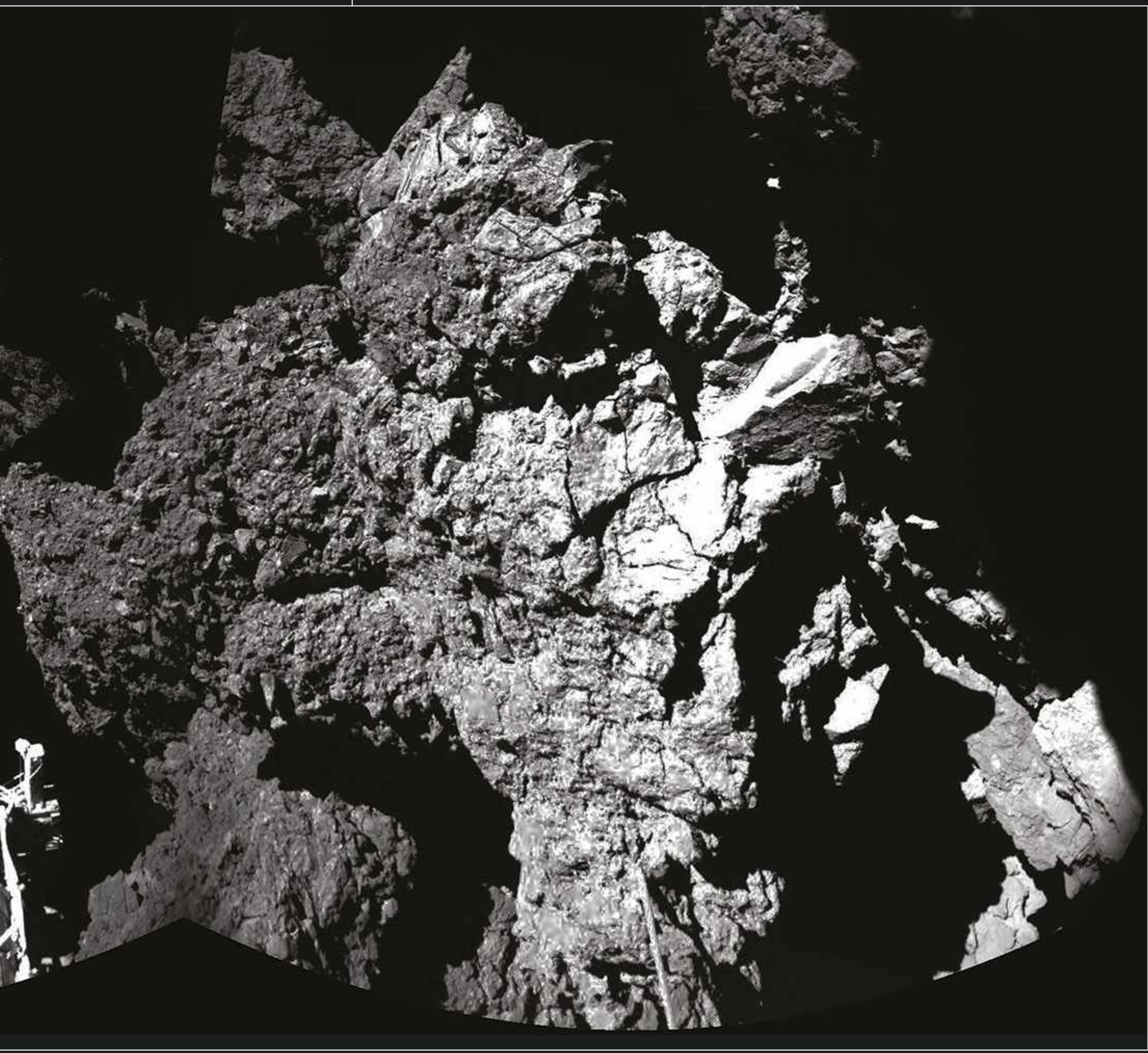
PHILAE LANDER
13 NOVEMBER 2014

This is the first panoramic image taken from the surface of a comet. Look carefully at Philae's shot of 67P/Churyumov-Gerasimenko and you'll spot the probe's three feet, circled. Philae's touchdown was confirmed at 16:03 UT on 12 November.

▼ Picturing a new world

PHILAE LANDER
13 NOVEMBER 2014

Zooming in on this section of Philae's initial panoramic image, the structure of the comet's surface is clear to see. This area was the only part of Philae's landing site where the light was good enough for such a detailed capture.



◀ Monolithic meeting

ROSETTA SPACECRAFT 11 NOVEMBER 2014

This image taken from 10km above the 'neck' of comet 67P/Churyumov-Gerasimenko reveals thin layers of rock (bottom right) that appear to have been compressed, adding weight to the theory that the comet could have been formed by a collision between two smaller bodies.

▲ Caught in a crag

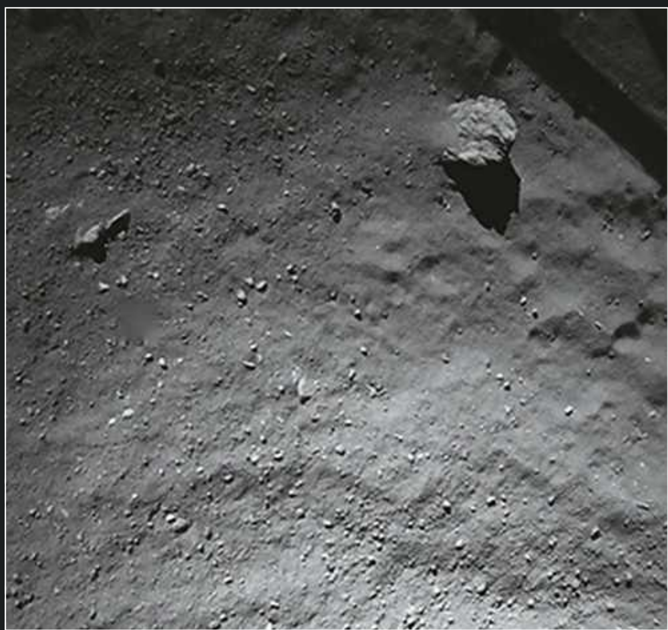
ROSETTA SPACECRAFT, 11 NOVEMBER 2014

This side-on view of the smaller lobe of comet 67P/Churyumov-Gerasimenko gives the space rock a dramatic, alien appearance. Mission controllers had a challenging task in choosing a suitable landing site for Philae amongst this rocky terrain.

▼ Brace for impact

PHILAE LANDER, 13 NOVEMBER 2014

At just 40m above the comet, Philae's ROLIS imager captured this view of its debris strewn surface. To give an idea of scale, the large boulder in the top right corner of the image is 5m across.



Homing in ▶

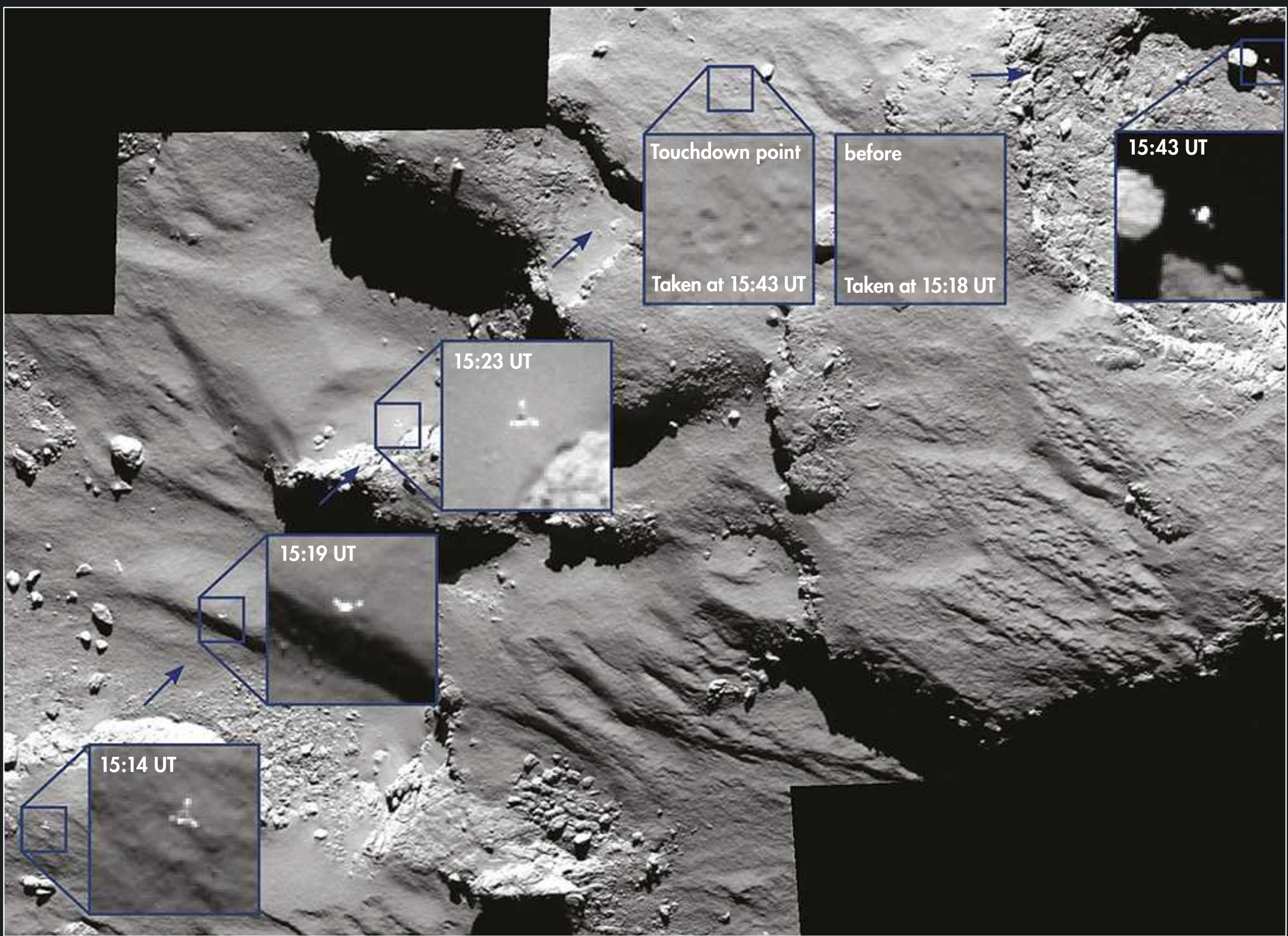
PHILAE LANDER
12 NOVEMBER 2014

Philae used its downward pointing ROLIS instrument to capture this image at a distance of 3km from the comet. As well as being used to record the lander's descent, the camera was also used to study the texture of the space rock's surface.

▼ Going, going, gone!

ROSETTA SPACECRAFT
17 NOVEMBER 2014

Rosetta's OSIRIS camera was able to capture the dramatic, 30-minute period as the Philae lander approached, and then bounced out from, its intended landing site. The probe can be seen, top right, drifting over a shadowy outcrop towards its final resting place.



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Bulletin

The latest astronomy and space news written by **Hazel Muir**

PLUS CUTTING EDGE

Our experts examine the hottest new astronomy research papers

Triumph for Rosetta's lander

The probe Philae has made history as the first to land on a comet

THE FIRST EVER spacecraft to land on a comet is being hailed as a great success, despite several setbacks. The lander Philae separated from the Rosetta probe, which orbits Comet 67P/Churyumov-Gerasimenko, and touched down on 12 November.

The lander failed to deploy the harpoons that should have anchored the probe to the comet. Instead, it bounced off the surface twice before coming to rest in the shadow of a cliff.

This means that its solar panels are not receiving as much sunlight as was hoped. Once the battery's inital charge depleted – after 57 hours – mission controllers lost contact with the probe. That was expected, but the hope was that the solar panels would recharge the battery and that Philae would 'wake up' and resume data collection. That seems unlikely for the time being.

Nonetheless, Philae returned useful data. "It has been a huge success, the team is delighted," says lander manager Stephan Ulamec from the German Aerospace Agency. "Despite the unplanned series of touchdowns, all our instruments could be operated and now it's time to see what we've got."

It's possible that Philae will eventually re-establish communication. "We still hope that at a later stage of the mission, perhaps when we are nearer to the Sun, we might have enough solar illumination to wake up the lander," says Ulamec.

The Rosetta orbiter will accompany the comet as it becomes more active en route to its closest encounter with the Sun in August. The mission should help us understand whether comets delivered water to the young Earth.

▸ See Comment, right

COMMENT
by Chris Lintott

I'm writing this from hallowed ground – just behind mission control at ESA's Darmstadt control centre. A few minutes ago, the team monitoring transmissions from Rosetta saw the signal it was receiving from Philae drop away. There are few of us here, and no cameras, but the atmosphere in this part of the room is sombre. Philae is not just a robot which functioned to the best of its ability, it is also the embodiment of our desire to explore the Solar System and a repository of hard work by a huge international team.

But the scientists aren't shedding tears. Up the road at lander control in Cologne, champagne corks are popping. Yes, they would have liked Philae to live, but the fact it returned data from what looks like all but one instrument has saved jobs and made careers. More importantly, it guarantees we will know more about the history of the Universe than we did before. We shouldn't mourn Philae – we should celebrate it.

CHRIS LINTOTT co-presents *The Sky at Night*

NEWS IN BRIEF

HOW VESTA GOT IN THE GROOVE

Deep grooves around the equator of Vesta formed due to a glancing impact at the asteroid's south pole, according to a new study.

In 2011, NASA's Dawn spacecraft showed that the grooves are probably due to a massive impact. Now simulations by Peter Schultz from Brown University in Rhode Island suggest it was struck at an angle of less than 40°, making interior rocks crack and forming deep canyons.

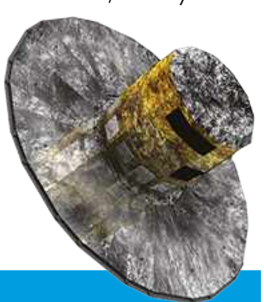
"Vesta got hammered – the whole interior was reverberating," says Schultz. "What we see on the surface is the manifestation of what happened in the interior."

GAIA SET FOR PLANET BONANZA

ESA's Gaia spacecraft, launched in 2013, could detect as many as 70,000 new planets.

Gaia's primary goal is to map roughly a billion objects, mostly stars. But a team led by Michael Perryman from Princeton University calculates that it could also reveal many new exoplanets if the mission lasts 10 years.

"It's anyone's guess how the field will develop as a result," he says.



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A dwarf's tantrum revealed

Astronomers have witnessed the true ferocity of a nova explosion

THE EXPANDING FIREBALL of a dramatic nova has been tracked and analysed in unprecedented detail. Astronomers say the observations should clarify exactly how and why these explosions occur on the surfaces of white dwarf stars.

In August 2013, Japanese amateur astronomer Koichi Itagaki discovered a 'new' star, subsequently named Nova Delphinus 2013. A nova occurs when hydrogen accumulates on the surface of a white dwarf, the hot shrunken remains of a Sun-like star that has run out of fuel. The hydrogen is siphoned off a companion star due to the white dwarf's gravitational pull.

"The white dwarf continually sucks hydrogen from its partner, forming an ocean on its surface. After drawing about as much mass as the entire planet Saturn, the pressure reaches a critical point, then boom!" says Peter Tuthill from the University of Sydney, Australia. "The stellar surface turns into one titanic hydrogen bomb hurling a fireball out into space."

With team leader Gail Schaefer from Georgia State University, Tuthill and colleagues analysed follow-up observations of Nova Delphinus 2013 made by a telescope array in California. They measured the size and shape of the nova on 27 nights over the course of two months.

The results suggest the nova occurred 14,800 lightyears away, and the expanding material had a surprisingly complex and slightly elliptical shape. The earliest observations showed the fireball was roughly the size of the Earth's orbit. It then expanded at a velocity of more than 600km/s until it was nearly the size of Neptune's orbit just 43 days after the initial detonation.

"Although novae often play second fiddle to their more famous cousins the supernovae, they are a remarkable celestial phenomenon," says Tuthill. "The ferocity of the expansion is breathtaking, engulfing a region the size of the Earth's orbit within a day, and passing Jupiter's orbit in less than two weeks."

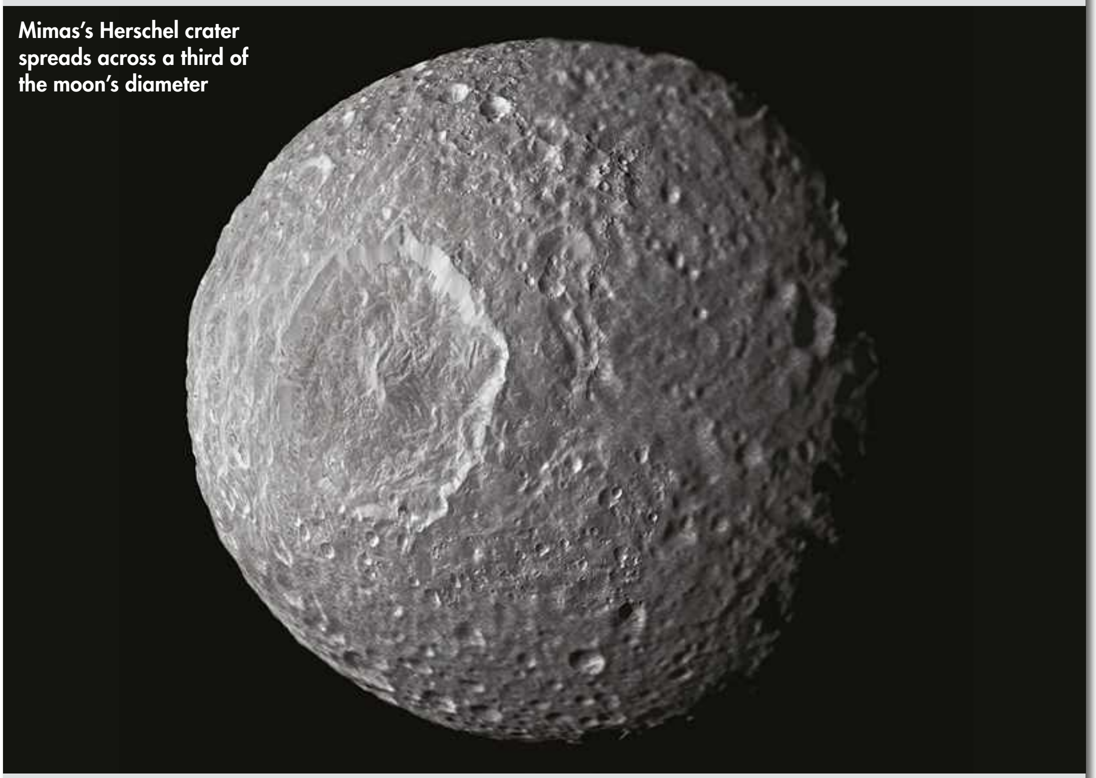
The observations also revealed that the fireball's outer layers became more diffuse and transparent as it expanded. After about four weeks, the cooler outer layers brightened, possibly due to the formation of dust grains that emit light at infrared wavelengths.

www.chara.gsu.edu

A white dwarf star pulls hydrogen from its larger companion to create the nova explosion

Mimas hides inner secrets

Tiny wobbles of this Saturnian moon suggest it has a strange interior



Mimas's Herschel crater spreads across a third of the moon's diameter

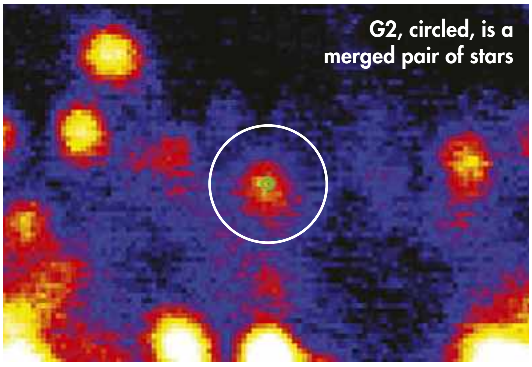
SATURN'S ICY MOON Mimas might harbour either a frozen core shaped like a rugby ball, or a liquid water subsurface ocean. The two suggestions follow an analysis of observations by NASA's Cassini spacecraft, which has measured how much Mimas wobbles as it orbits Saturn.

This gave some clues to the moon's interior structure. "Something is not right, so to speak, inside Mimas," says analysis leader Radwan Tajeddine from Cornell University in Ithaca, New York. "The amount of wobble we measured is double what was predicted."

An oblong core that solidified soon after the moon's formation could explain this. Alternatively, Mimas might have an underground ocean, making it a member of the exclusive club of 'ocean worlds' that includes several moons of Jupiter and two other moons of Saturn, Enceladus and Titan.

www.nasa.gov/cassini

BLACK HOLE DODGER IDENTIFIED



G2, circled, is a merged pair of stars

A STRANGE OBJECT orbiting perilously close to the giant black hole at the centre of the Milky Way has turned out to be the product of merged stars.

For years, astronomers have been puzzled by the object, called G2. Initially they thought it was a hydrogen gas cloud destined to be ripped apart by the immense gravity of the supermassive black hole.

G2 made a close approach to the black hole in the summer of 2014 and was monitored using the Keck Observatory in Hawaii. If it was a gas cloud it should have been torn apart, creating energetic flares, according to Andrea Ghez from the University of California at Los Angeles.

"G2 survived and continued happily on its orbit – a simple gas cloud would not have done that," she says. "It was basically unaffected by the black hole, and there were no fireworks."

Instead, after studying G2, Ghez's team concludes that it is probably a pair of binary stars that merged to form an enormous star cloaked in gas and dust.

www.keckobservatory.org

NEWS IN BRIEF

COMET PUMMELS MARS WITH METEORS

A comet passed within 139,500km of Mars, less than half the Earth-Moon distance, on 19 October, and was monitored by NASA's MAVEN probe.

Comet dust triggered a huge meteor shower in Mars's atmosphere and added ions including sodium, magnesium and iron. "A Martian would have seen many thousands of shooting stars per hour, so it must have been a spectacular event," says MAVEN scientist Nick Schneider from the University of Colorado.

GALAXIES SHAPED UP SOONER

A discovery that galaxies developed features such as discs or spiral arms up to two billion years earlier than expected has been made with the help of volunteers sorting Hubble images as part of the Galaxy Zoo project.

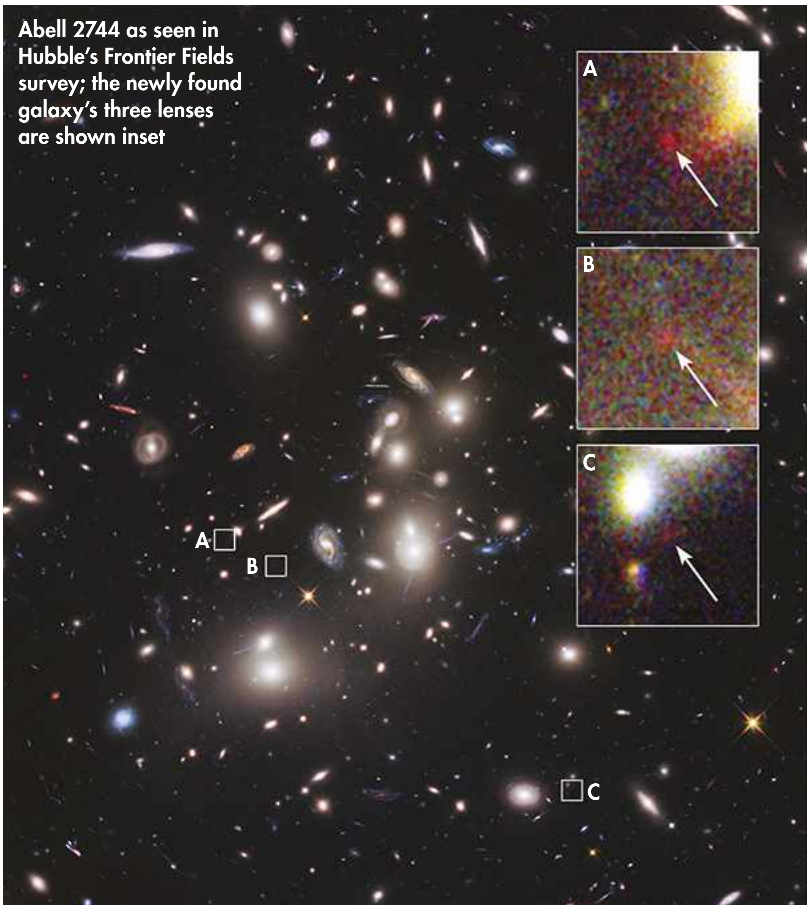
Key structures formed when the Universe was just three billion years old. "Some galaxies settle very early on in the Universe," says scientist Brooke Simmons from the University of Oxford.

CUTTING EDGE

Our experts examine the hottest new research

In a galaxy far, far away...

Gravitational lensing has helped us uncover a galactic fossil 13.2 billion lightyears away



Abell 2744 as seen in Hubble's Frontier Fields survey; the newly found galaxy's three lenses are shown inset

NASA/ESA/A. ZITRIN (CALIFORNIA INSTITUTE OF TECHNOLOGY/PASADENA AND J. LOTZ/M. MOUNTAIN/A. KOEKEMOER AND THE HFF TEAM (SPACE TELESCOPE SCIENCE INSTITUTE BALTIMORE MD.)

This month's paper proudly announces the discovery of a faint blob at an enormous distance from Earth, so distant that its light has taken more than 13 billion years to reach us. It is the fossil remnant of the early Universe, one of only a handful which have been detected from such early times, and a clue to the very earliest stages of the processes that produced the Universe we see today.

Discovered in images taken by the Hubble Space Telescope's Frontier Fields survey, some of the deepest ever taken, it remains nothing more than a smudge. It is so faint that effective follow-up is all but impossible, and the smudge is the best view we'll get for decades to come. So why should we care? For one thing, we see the object not once, but three times. It happens to lie behind a distant galaxy cluster, and so its light has been bent on its passage towards Earth. The cluster magnifies the distant image, but it's an imperfect telescope, and there are several paths light can take to reach us. That's the key to the problem; the position of these multiple images depends on the distribution of mass within the cluster (which we understand) and the distance to the lensed galaxy (which we want to calculate).

Astronomers already suspected this was a distant galaxy based on the colour of its light. Start with the assumption that there's nothing special about the galaxy, and you can predict its likely colour at different distances. This so-called 'photometric redshift' is an estimate, but a good one, and this system suggested a redshift above 9, equivalent to a light travel time of 13.2 billion years. The Universe, remember, is 13.8 billion years old.

When dealing with rare objects, there's always the nagging feeling that estimates might be wrong – that the galaxy might be odd – and so independent confirmation is critical. That's what the multiple lensed images provide, with a best-fit model suggesting a redshift of 9.8 and a light travel time of 13.23 billion years.

> "What's important is not that the galaxy exists, but we can be reasonably sure how distant it is"

The importance of this discovery is thus not that the galaxy exists, but that we can be reasonably sure how distant it is. Two things immediately follow as a consequence. Firstly, the galaxy is star-forming at a rate of a solar mass's worth of stars every three years, doubling its stellar mass every 500 million years. This is rapid for a galaxy that only weighs in at 40 million solar masses and so we're seeing the first, rapid burst of star formation.

Secondly, the system is smaller than expected, no more than a few thousand lightyears across. We had expected galaxies in the early Universe to be small, but not that small – it's even smaller than the tiny satellite galaxies around the Milky Way. It could be a one-off, but it does make me shake my head in wonder that we can see this thing at all.

CHRIS LINTOTT is an astrophysicist and co-presenter of *The Sky at Night* on BBC TV. He is also the director of the Zooniverse project.

CHRIS LINTOTT was reading... *A geometrically supported z ~ 10 candidate multiply imaged by the Hubble Frontier Fields Cluster A2744* by Adi Zitrin et al
Read it online at http://iopscience.iop.org/2041-8205/793/1/L12/

Milky Way starves local dwarfs

Our Galaxy raids star-building gas from its neighbours

Our greedy Milky Way slurps raw materials for new stars from its neighbouring dwarf galaxies

THE GRAVITY OF our Galaxy strips gas out of nearby dwarf galaxies, a new study suggests. Effectively, the Milky Way robs them of the raw materials for star formation.

Using the Green Bank Telescope in West Virginia – the world's largest fully steerable radio telescope – a team led by Kristine Spekkens from the Royal Military College of Canada showed that dwarf galaxies up to about 1,000 lightyears from the edge of the Milky Way have very little hydrogen gas. Beyond that, dwarf galaxies are teeming with star-forming material.

"What we found is that there is a clear break, a point near our home Galaxy where dwarf galaxies are completely devoid of any traces of neutral atomic hydrogen," says Spekkens.

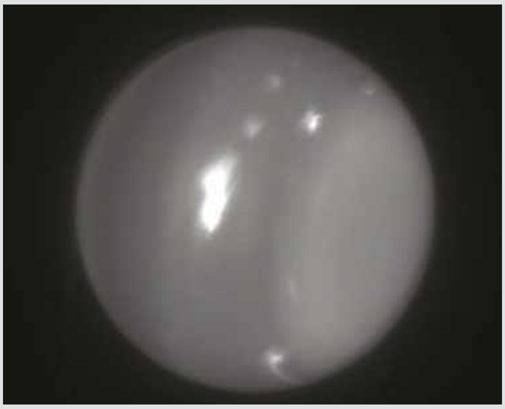
www.gb.nrao.edu

STORMS RAGE ON URANUS

THE NORMALLY TRANQUIL face of Uranus has become increasingly stormy. Late last year, enormous cloud systems on the planet became so bright that even amateur astronomers could see clear details formed in the planet's hazy blue-green atmosphere.

"The weather on Uranus is incredibly active," says Imke de Pater from the University of California at Berkeley, whose team detected several large storms in the ice giant's northern hemisphere. The bright clouds probably form when gases such as methane rise in the atmosphere and condense into highly reflective clouds of methane ice, but what triggered the storms is unclear.

www.keckobservatory.org



The bright spots in the atmosphere of Uranus may be the result of methane ice reflecting sunlight

Looking back The Sky at Night

▲ The supernova recorded by the Chinese in 1054 can still be seen today as the Crab Nebula, M1

January 1990

On 21 January 1990, the intriguing title for *The Sky at Night* was 'Tales of the Unexpected'. The programme discussed short-lived astronomical events such as bright new comets, supernovae and aurorae.

Ancient Chinese texts reveal that people have noticed new comets blazing through the skies for millennia. In 1705, English scientist Edmond Halley first predicted when a comet (later named after him) would return, after recognising it must make periodic trips to the inner Solar System.

There are several naked-eye supernovae in the historical record, including one seen by Chinese astronomers in 1054. Other fleeting events include gamma-ray bursts, bright flashes of radiation that last from a few milliseconds to several minutes. They were discovered by US military satellites in the 1960s and are now linked to energetic explosions in distant galaxies.

NEWS IN BRIEF

ORPHAN STARS' COSMIC GLOW

The dark space between galaxies is surprisingly bright in the infrared according to results from a new NASA experiment. The glow is thought to come from stars that have been flung out of their galactic homes.

"We think stars are being scattered out into space during galaxy collisions," says Michael Zemcov from the California Institute of Technology, whose team analysed observations by cameras on rocket flights in 2010 and 2012 as part of a project called the Cosmic Infrared Background Experiment.

Zemcov suggests galaxies don't have clear boundaries, but instead stretch out to great distances, forming a vast, interconnected sea of stars.

NEW TARGETS FOR NEW HORIZONS

Astronomers have used the Hubble Space Telescope to identify three icy Kuiper Belt objects NASA's New Horizons spacecraft could visit after it flies past Pluto in July. Although far smaller than Pluto, they are around 10 times larger than a typical comet.

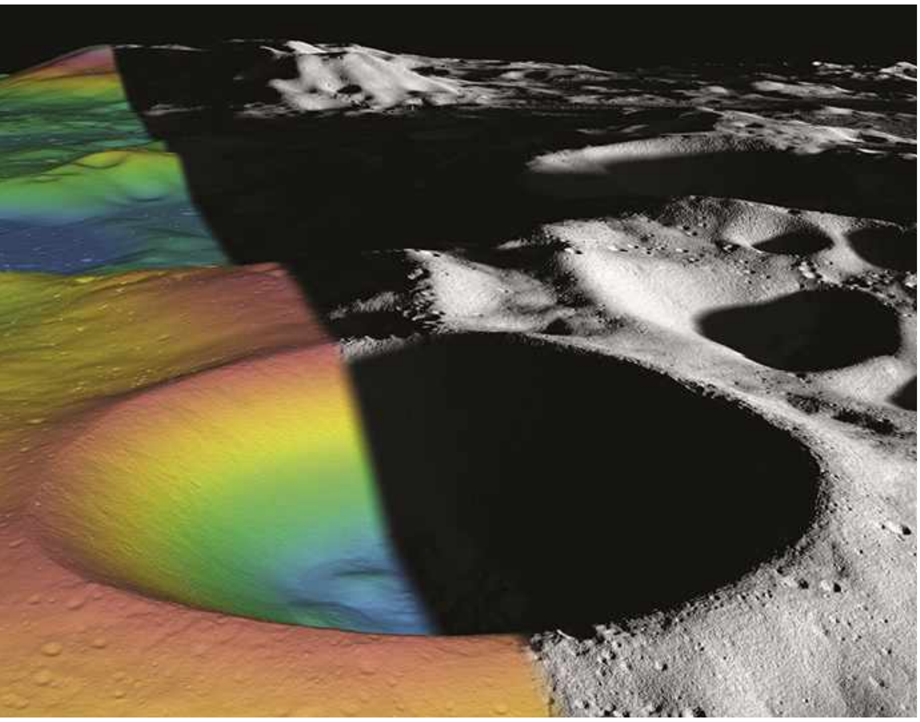
T. ARAI/UNIVERSITY OF TOKYO, NASA/ESA AND G. BACON (STSCI), NRAO/AUI/NSF, IMKE DE PATER (UC BERKELEY) & W. M. KECK OBSERVATORY IMAGES, ISTOCK

CUTTING EDGE

Our experts examine the hottest new research

A place in the Sun

New terrain models could help find the perfect spot to set up a base on the Moon



▲ **Sunlight is critical for power generation, while dark crater floors could also hold a vital resource in the form of water-ice**

NASA/ZUBER/M.T. ET AL/NATURE 2012

When you're thinking about long-term exploration of the lunar surface, either by robotic landers or human astronauts, one of the most important considerations is power. It's almost certain that future lunar settlements will rely on solar energy for power, so a key consideration when choosing a site is going to be how much sunlight is available to your solar panels. This month's paper explores one way we might be able find a suitable spot.

Equatorial regions of the Moon are routinely plunged into darkness for weeks at a time and this would be disastrous for maintaining a power supply based on solar energy. However, because the Moon is only inclined at 1.5° it sits almost perfectly upright, meaning that some highland regions around the poles receive almost continuous sunlight. On the flip side, the bottoms of some polar craters experience permanent shadow. But these cold traps may harbour significant amounts of water-ice, a vital in-situ resource for a manned Moon base to exploit for drinking water and (via electrolysis) oxygen to breathe.

Computer models are vital to predicting which polar regions receive the most reliable sunlight levels, and will therefore make the best lunar landing sites. Such an illumination map can be calculated from an accurate Digital Terrain Model (DTM) – essentially an Ordnance Survey map of elevations across the landscape.

In this study, Philipp Gläser of the Technical University Berlin and colleagues built their DTM of a 20km-wide square of interest just off the Moon's south pole by using the ultra high-res, laser-based altitude data now being generated by the Lunar Reconnaissance Orbiter. They used their terrain model to calculate the changing sunlight levels falling on the contoured landscape during the Moon's orbit and also how this monthly average of illumination varies with the wobbling of the Moon's axis over its 19-year precession cycle.

Gläser focused on three particular highland regions near the south pole as potential landing sites. Two of these are on the high rim of crater Shackleton, and the third is positioned on a 'connecting ridge' running between Shackleton

> **"It's almost certain that future lunar settlements will rely on solar energy for power"**

and crater de Gerlache. The maps showed that while there are no spots receiving constant sunlight (the Sun was at least partially obscured behind high ground on the horizon for some of the time), the three target regions all had parts that received more than 70 per cent illumination. And if you were to raise the solar panels to just 2m above the ground, this increases to up to 92 per cent illumination.

Gläser found that the best site overall is the connecting ridge as it receives the greatest illumination levels over the widest area, and the longest you would need to endure darkness is only four or five days at a time. And importantly for permanent habitation over the decades this still holds true over the 19-year precessional cycle.

So, if you happen to be planning your own excursion to the south lunar pole, you'll want to touch down right at 89.4399°S, 222.8524°E!

LEWIS DARTNELL is an astrobiologist at University of Leicester and the author of *The Knowledge: How to Rebuild our World from Scratch* (www.the-knowledge.org)

LEWIS DARTNELL was reading… *Illumination conditions at the lunar south pole using high resolution Digital Terrain Models from LOLA* by Philipp Gläser et al
Read it online at www.sciencedirect.com/science/article/pii/S0019103514004278

What's on

Our pick of the best events from around the UK

PICK OF THE MONTH

Is the All-There-Is all there is?

Winchester Science Centre, Winchester, 14 January 4.30pm and 6.30pm

Dark matter is thought to exist throughout the Universe; inset, Dr Roberto Trotta

Imperial College London's Dr Roberto Trotta addresses one of the most enigmatic and mysterious areas of astrophysics at the Winchester Science Centre this month, that of dark matter.

The 'All-There-Is' is in fact the Universe: a term Trotta coined in his recent book *The Edge of the Sky*, in which he explains core conceits in cosmology using only the 1,000 most common words in the English language. In what promises to be a fascinating lecture, he will review the evidence for the existence of dark matter, which is thought to make up 95 per cent of the Universe, as well as his own theories on the nature of dark matter and dark energy.

Following the lecture, there will be a short planetarium show highlighting the evening's best observing sights. Tickets cost £8 for the early lecture and £10 for the later showing.

www.winchestersciencecentre.org

BEHIND THE SCENES

THE SKY AT NIGHT IN JANUARY

BBC Four, **11 January**, 10pm (first repeat BBC Four, **15 January**, 7.30pm)*

The camera aboard the Gaia space scope is the most advanced ever sent into space

THE BILLION PIXEL CAMERA

The Milky Way is a magnificent sight in the night sky, but we know surprisingly little about it. The Gaia space telescope will change that. This month the team visit the factory that made the astonishing sensor at the heart of the mission, which will allow us to see our Galaxy as we've never seen it before.

Check www.bbc.co.uk/skyatnight for subsequent repeat times

ILLUSTRIS COLLABORATION, CASSINI IMAGING TEAM/CASSINI PROJECT/NASA, ESA–D. DUCROS 2013

The Theory of Everything

At cinemas nationwide from 1 January 2015

Eddie Redmayne stars in The Theory of Everything, the stunning new biopic from director James Marsh charting the life of Prof Stephen Hawking. Delve into Hawking's world, from his time as an undergraduate at the University of Oxford to the development of his most famous scientific principles.

What makes the Milky Way special?

Wakefield and District Astronomical Society, Horbury Academy, Horbury, 15 January, 7.30pm

Join Wakefield and District Astronomical Society this month and hear Dr Chris Lintott discuss why our Galaxy, the Milky Way, differs from the many millions that surround it. Tickets cost £3 to non-members.

www.wakefieldastronomysociety.co.uk/index.html

International Year of Light 2015

Stirling Astronomical Society, Smith Museum and Art Gallery, Stirling, 9 January, 7.30pm

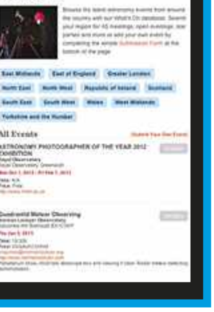
Stirling Astronomical Society marks the UN's International Year of Light – a celebration of the science and technological uses of light – with a talk from Prof Martin Hendry from the University of Glasgow. He will be discussing how Danish astronomer Ole Rømer measured the speed of light using eclipses of Jupiter's moon Io in 1676.

www.stirlingastronomicalsociety.org.uk

MORE LISTINGS ONLINE

Visit our website at **www.skyatnightmagazine.com/whats-on** for the full list of this month's events from around the country.

To ensure that your talks, observing evenings and star parties are included, please submit your event by filling in the submission form at the bottom of the page.



A PASSION FOR SPACE

with **Maggie Aderin-Pocock**

The Sky at Night presenter reflects on a victory for European unity: a historic landing on a distant comet

I hate to admit it, but my last *Passion for Space* was a real understatement. I cannot remember the last time that I laughed, cried or generally shouted so much in public or among strangers, such was the brilliant success of the Rosetta mission and its Philae lander.

Overnight on 11 November, the *Sky at Night* team was in mission control at ESA's European Space Operations Centre in Germany, waiting to see if Philae was to be released at all. Confirmation came at 8.30am on the 12th: it was go for Philae. This marked the start of a seven-hour wait as the probe wafted towards the surface of the comet under the weakest of gravitational pulls imaginable.

Philae's seven-hour descent was agonising for everyone following the mission

ESA/ATG MEDIALAB; COMET IMAGE: ESA/ROSETTA/NAVCAM

A nearly unbearable seven hours and seven minutes later, the signal came through confirming touchdown had been achieved. A wild roar ripped through the press room, followed by a collective sigh of relief. This was slightly mitigated by the rather worried face of one of the engineers from lander control. He reported that although touchdown was confirmed, the telemetry coming in from Philae's instruments did not make sense.

By analysing the telemetry over the next 24 hours, mission controllers worked out that Philae had reached the surface but had then performed a 'super bounce', which lasted for two hours and saw it rise 1km from the comet's surface. It had then landed intact but in a bad location, where only a small portion of it solar panels were illuminated by sunlight. In this position Philae was totally dependent on its 10-year-old onboard battery, which could only power it for around 60 hours.

Race against the clock

At this stage we transferred to lander control to speak with the instrument teams, who were all vying for the limited battery power available on Philae. For many of the scientists there this was their life's work at stake, and yet they all worked in a spirit of focused cooperation – each taking it in turns to get data so every instrument could be used.

There were also times that were reminiscent of NASA's Apollo 11 mission, as teams tried to use onboard instrumentation to reorientate the lander to give it more sunlight. Unfortunately, these operations failed and Philae's battery eventually ran out of power, but not before a wealth of data had been acquired for each of the Philae instruments.

The few days I spent out at ESA were quite transformative for me: one of the things I took away from the whole experience was a feeling of reassurance. That 11 November was also a special Armistice Day, when we remembered the death and destruction caused by the First World War 100 years before. Yet there was a definite show of European unity on the 12th, as scientists from across the EU worked together to get the maximum amount of science data from a space probe some half a billion km away. It showed me how much can change over a period of 100 years and also made me feel that if we can achieve this, then what else might we be able to do?

Maggie Aderin-Pocock is a space scientist and co-presenter of *The Sky at Night*

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JON CULSHAW'S EXOPLANET EXCURSIONS

Jon's eclipse chasing desire leads him to Piscis Austrinus for an interstellar perspective

One of the most spectacular coincidences on Earth is the very fact that total solar eclipses take place: that the Sun is both 400 times larger than the Moon and 400 times further away from us. This wonderful fluke means that the Sun and Moon appear the same size, allowing our Moon to perfectly block the solar disc and give us the glory of totality.

I heartily agree with Sir Patrick Moore's assertion that total solar eclipses are the most incredible sight in all nature and I'm giddy to discover how they might appear in other parts of the Universe around other stars. So I'm steering the cruiser globe to Fomalhaut, a young blue star 25 lightyears from the Sun and the brightest star in the constellation of Piscis Austrinus, the Southern Fish.

Fomalhaut is believed to be around 200 million years old and is approximately twice the mass of our Sun. This youthful star is very much faster, fiercer and more active than our middle-aged home star: the stellar equivalent of a 19-year-old knocking back high-caffeine energy drinks at Reading Festival in contrast to a more matured soul, who much prefers a quiet brew with a macaroon watching *Dickinson's Real Deal*.

Orbiting this star is the gas giant Fomalhaut b, a world estimated to be two or three Jupiter masses. I'm going to settle in the region of this planet – one of the first extrasolar worlds to be imaged directly – to assess where best to observe a total Fomalhaut eclipse from.

This planet is around 115 AU from Fomalhaut, rather far back to observe the kind of eclipses familiar on Earth, so I cruise closer into the habitable zone until I'm just 2.5 AU from the star. Here, I have the supreme fortune to locate a rocky world sized somewhere between Mars and Earth.

By steering the Cruiser Globe to a point where this rocky world appears in its 'new' phase, and then reversing to where it appears identically sized to Fomalhaut itself, I have an amazing chance to witness a beyond breathtaking alien eclipse. I shall name this rocky world 'Totalis' in honour of the exo-eclipse it's allowing us to see.

What a majestic, eerie sight, a total stellar eclipse. Surrounding the solid black disc of the 'new' Totalis, the Fomalhaut corona pierces outwards with elongated, spindly rays, like the outstretched arms of someone doing a funny dance.

This corona is a distinct silvery blue and visibly fast moving, as if it's being blown in a cosmic breeze. The shape is evocative of medieval sketches of the Sun. Prominences shimmer in pure, piercing white, very differently to the Sun's prominences of burgundy flecks during totality seen from Earth. At the end of the eclipse, the valleyed terrain of Totalis gives three separate diamond ring effects at the one, three and four o'clock positions.

To witness another variety of total eclipse is a breathtaking exoplanetary vision. I could get the taste for this: eclipsed red giant viewed through dazzling auroral activity on an icy exoworld, anyone?

Jon Culshaw is a comedian, impressionist and guest on *The Sky at Night*

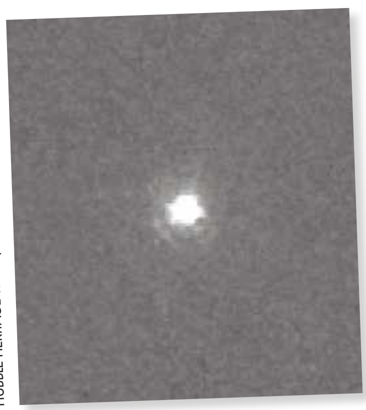
MAIN ILLUSTRATION BY MARK GARLICK, PHOTO: EMMA SAMMS

This month's top prize: four Philip's books

The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's. Heather Couper and Nigel Henbest's *Stargazing 2015* is a month-by-month guide to the year and you'll be able to find all the best sights with Patrick Moore's *The Night Sky*. *Stargazing with Binoculars* by Robin Scagell and David Frydman contains equipment and observing guides, and you'll be viewing planets, galaxies and more with Storm Dunlop's *Practical Astronomy*.

PHILIP'S

▼ **Circumstellar material can be seen around the star that exploded as supernova 2014J**



NASA/ESA/A. GOOBAR (STOCKHOLM UNIVERSITY) AND THE HUBBLE HERITAGE TEAM (STSCI/AURA)

Interactive

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Email us at inbox@skyatnightmagazine.com

MESSAGE OF THE MONTH

There's no place like dome






▲ **An impressive back-garden observatory is possible with engineering skills and careful avoidance of buried utilities**

I am in the final stages of completing my project to build a 2.4m dome out of wood. I have almost finished the building of the dome and constructed the base, but have still to build the deck and make the two halves fit together.

The dome will be supported and rotate on the base using 12 ball transfer unit bearings (similar to the balls you find on the base of old computer mice). I am having a load ring manufactured locally for the bearings to run on rather than directly on the plywood itself. In most places the plywood is doubled up not only to aid in the construction of the larger ribs and base ring but also to add strength to the overall structure. In order to make the whole design waterproof I have fibreglassed it and applied a final smoothing resin coat impregnated with a colour chosen by my wife to fit in with the surrounding shrubs.

I have included a variety of photos showing the whole process all the way from site selection – including the moving of a broadband cable that I discovered while digging the pier hole!

By the way, I love the magazine and now that I have a permanent setup I hope to be able to improve my astrophotography skills. The pier will hold my Orion Atlas EQ6 mount along with an Orion 10-inch astrograph.

Stephen Charnock, via email

Good luck with the rest of this exciting project, Stephen. For more on home observatories, see our 16-page pullout this issue. ***– Ed***

Oort or noort?

With regard to the question raised by David Tart in December 2014's *Interactive* (page 25), who asked "What hard evidence is there for the existence of the Oort cloud?": if the Oort cloud does exist around our Solar System, then one would think that such a cloud would also exist around other planetary systems in our Universe. If you go back to Chris Lintott's *Cutting Edge* in

SOCIAL MEDIA

WHAT YOU'VE BEEN SAYING ON TWITTER AND FACEBOOK

Have your say at **twitter.com/skyatnightmag** and **facebook.com/skyatnightmagazine**

@skyatnightmag asked: What does the Philae landing mean to you?

Patricia Antunes: It means nothing is really impossible as long as we believe in it! Don't give up Philae.

@phrixus: The Philae landing proves that we, as humans, can do anything. Imagine what we'd achieve if we funded science as we fund war.

Mick Cassidy: Anything is possible, nothing is impossible. We can achieve anything as proved over years and years of evolution.

@DaveCJLP: That we can plan long term to achieve something incredibly difficult. So let's send another probe to Titan. With a boat!

@JP_Astronomy: Philae amazed me. I wasn't around to see the Moon landings, but Philae was another giant leap for mankind.

@Johnimus_Prime: And boy, did it leap!

Lín Rhys: It means we can go farther and do more than we ever could before… and we should! Exploration is in our nature, and should be in our future!

@nillchill: It was inspiring scientific history. It shows us just what we can do when we all work on discovering and not on conflicts.

December (page 14) concerning supernova 2014J, Chris refers to circumstellar material around the star, which in this case had exploded into a supernova. The light from the exploded star was so intense that the reflected light from the star's surrounding material had shown up on the photo as a ring of light around the supernova. Could this be evidence that an Oort cloud had existed around that star?

Brian Drew, Doncaster

Researchers are looking at other planetary systems within our own Galaxy for evidence of exo-Oort clouds. As for supernova 2014J in M82, they are still investigating that. Due to the great distance involved, however, it is unlikely that they'll be sure whether or not any material around the star is an Oort Cloud. ***– Elizabeth Pearson, staff writer***

Alice in Astroland

This is my four-year-old daughter Alice – the next generation of astronomer. The telescopes in the image are a 6-inch iStar Optical f/8 refractor and a Celestron C9.25 Schmidt-Cassegrain on an Astromount. The picture was taken in my home-built observatory near Oxford.

Matt Armitage, Oxford

What a heart-warming picture Matt, Alice seems dwarfed by the scope but what a great place to develop a passion for the stars! ***– Ed***

▲ **Daughter Alice carries out a last-minute daylight check for unwanted flexure in Matt's observatory setup**

The great bare

I wanted to write to you about fellow astronomer Amanda King who has, along with 12 other brave ladies from Cornwall, created a cosmic calendar in the style of the Calendar Girls, with all the proceeds going to the Cornwall Hospice Fund. She has not only managed to get sponsorship for the printing of the calendar so all of the £10 price goes directly to the charity, but also got the excellent background photography donated by local astrophotographers Paul Hughes and Karl Stephens.

Carolyn Kennett, via email

Brave ladies indeed, I hope the calendar does its job and raises lots of money for this worthy cause Carolyn. ***– Ed***

Flocking success


SKILLS

How to

Flock a Newtonian telescope

TOOLS AND MATERIALS

I refer to your August 2014 article 'How to Flock a Newtonian' (page 81). I have a 12-inch UK Orion Optics SPX Dobsonian and took the plunge in deciding to flock it in September. I followed all your instructions, but had to wait until October to check my results due to poor conditions. Our club, the Northern Ireland Amateur Astronomy Society, was at a dark sky site on 28 October and that was my first opportunity to see the results. What a difference the flocking made. The Andromeda Galaxy is usually a bright blob, but the effect of the flocking was dramatic and I got the best view I have ever had of it. All the members present agreed. The background was so much darker and the star fields were so rich, all in all a great success. You, Steve Richards, are a great scope doctor!

Derrick McCourt, Northern Ireland

It's amazing how simple improvements to your astronomical equipment can have a dramatic effect on the observing experience. It sounds like you've done an excellent job of flocking your Dobsonian telescope and I hope it continues to deliver great views of the night sky. ***– Steve Richards***

OOPS!

• In November's issue of *BBC Sky at Night Magazine* we incorrectly stated that Mount Teide in Tenerife is 3,260m high. The summit is actually at 3,718m.

Hotshots

This month's pick of your very best astrophotos

▲ M13

PETER MARTIN, IRELAND, 30 APRIL 2014

Peter says: "I took two sets of exposures for this shot: one set of fairly short ones for the core and another much longer set to capture the faint outer stars. I then blended them so that the core wouldn't burn out when I brightened the outer stars."

Equipment: Starlight Xpress H694 CCD camera, Orion Optics AG10 telescope, Avalon linear mount.

***BBC Sky at Night Magazine* says:** "From the intricate resolution of individual stars in the cluster to the presence of background galaxies and the expert balance of colour, there is a great deal to admire in Peter's stunning composition."

About Peter: "I started with astronomy after seeing *Stargazing LIVE* in January 2012. I did visual observing until July of that year,

when I took my first picture of the Dumbell Nebula with a DSLR. I can still remember the feeling of seeing it pop up on the DSLR screen in full colour after months of seeing it in black and white through the eyepiece. I was hooked. It's been a steep learning curve but I would encourage anyone to take it up."

◀ Comet C/2013 A1 and Mars

ANDREA PISTOCCHINI
GERMIGNAGA, ITALY
22 OCTOBER 2014

Andrea says: "On the last day possible (for my location) I managed to image the conjunction of Mars and comet C/2013 A1 Siding Spring. It was the fifth time that I had tried to capture them. The first two were spoiled by clouds, the third moisture, the fourth bad seeing."

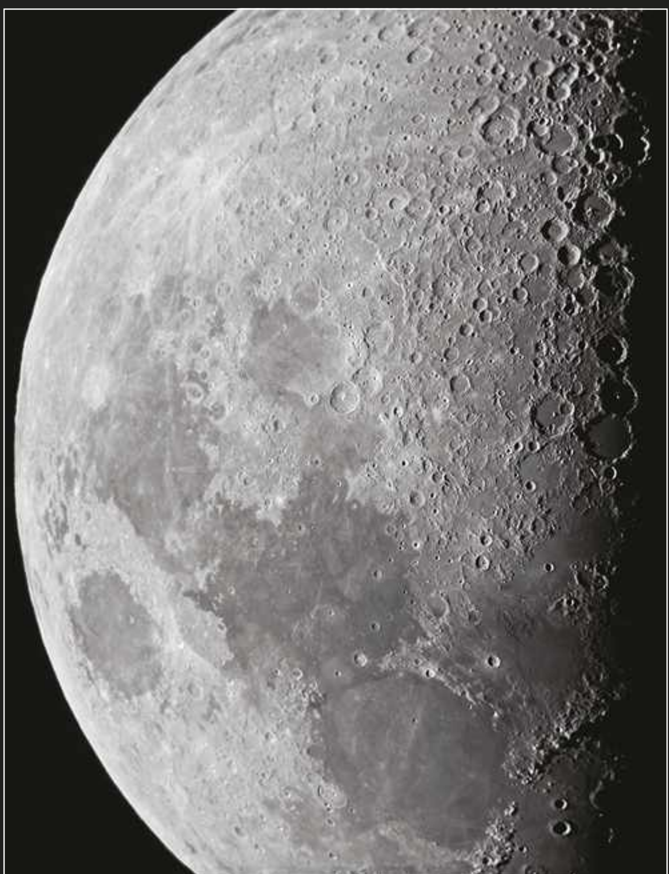
Equipment: Canon EOS 450D DSLR camera, Tecnosky 80/480 telescope, NEQ6 Pro mount.

▼ The Moon

JOHN O'MAHONY, SYDNEY, AUSTRALIA, 12 OCTOBER 2014

John says: "This image was created from a stack of seven photos taken during exceptional seeing conditions from my backyard in Sydney."

Equipment: Canon EOS 7D DSLR camera, Meade 8-inch Schmidt-Cassegrain.



▲ Sunspot NOAA 12192

PETE WILLIAMSON
SHROPSHIRE, 25 OCTOBER 2014

Pete says: "This is a large sunspot taken in white light."

Equipment: ZWO 120mm CCD camera, Bresser 6-inch refractor.

▲ The Cave Nebula

KFIR SIMON
ISRAEL
14 OCTOBER 2014

Kfir says: "I like the great contrast between the blue and reddish orange in this image – representing Ha and SII light. This reflects the different materials composing this nebula."

Equipment: SBIG ST8300M CCD camera, 10-inch ASA telescope, ASA DDM 60 Pro mount.

◀ M31

JESPER SUNDH
LYON, FRANCE, 4 NOVEMBER 2014

Jesper says: "This is an 11-panel mosaic with a total of 200 hours and 35 minutes integration time."

Equipment: Atik 460EX CCD camera, Sky-Watcher ED80 telescope, Astro-Physics 1600GTO mount.

▲ NGC 7023

SHAUN REYNOLDS
NORFOLK, SEPTEMBER AND OCTOBER 2014

Shaun says: "I wanted to go deep and capture all the dust stretching out from the hot stars at the centre of this reflection nebula, which required 15 hours of exposure time. I particularly like this nebula as it presented a challenge in capturing both the dust and detail at the centre."

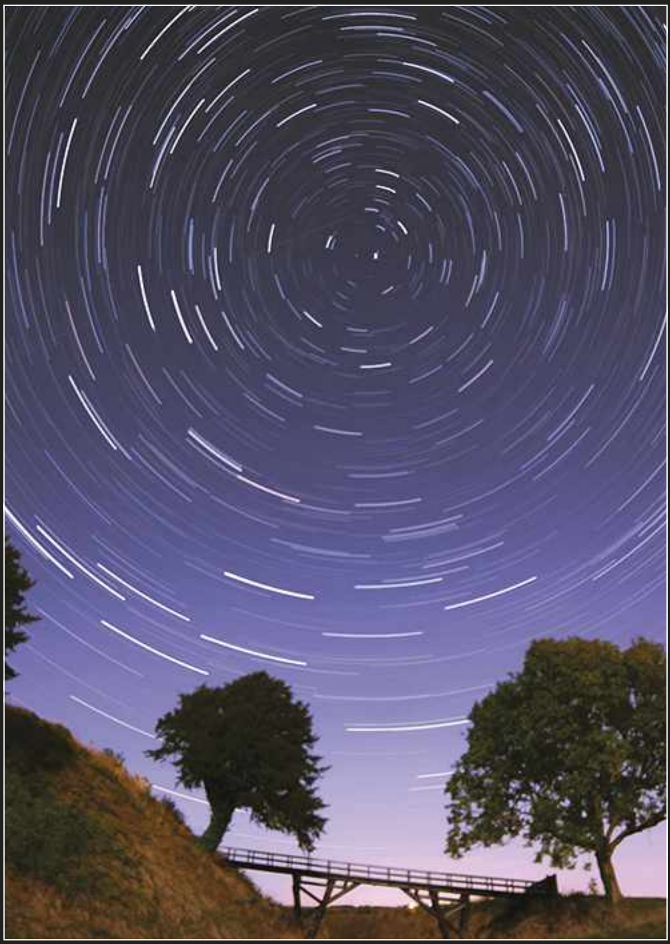
Equipment: SXV 694 mono cooled CCD camera, Takahashi E-180 telescope, Paramount GT-1100S German equatorial mount.

NGC 6914 ▶

BOB FRANKE
ARIZONA, US
17 AUGUST 2014

Bob says: "This remarkably beautiful nebula complex is located at the heart of the constellation of Cygnus. Just left of centre is NGC 6914, a complex of the three blue reflection nebulae. The two on the right are cataloged as vdB 132; to the left and slightly lower is vdB 131."

Equipment: SBIG STF-8300M CCD camera, Takahashi FSQ-106ED telescope, Losmandy G11 mount.



▼ NGC 7822

CHRIS GRIMMER, NORWICH, 31 OCTOBER 2014

Chris says: "This image data was captured over three nights across one week, possibly my quickest image ever, due to unusually clear skies."

Equipment: SXVR H694M CCD camera, William Optics GT81 triplet refractor, iOptron CEM60 standard mount.

▲ Star trails

BOB FORD,
WILTSHIRE, SEPTEMBER 2014

Bob says: "These star trails were taken at Old Sarum, the English Heritage site in Wiltshire. The Moon was waning gibbous, creating a blue sky under long exposure, and the trees very kindly pointed out Polaris for me!"

Equipment: Canon EOS 110D DSLR camera.

NGC 1398 ▶

DAN CROWSON
NEW MEXICO, US, 22 OCTOBER 2014

Dan says: "This is the first of several images I captured from five 'black zone' sites on my way to an astrophotography seminar in Arizona. My goal was to image objects that were too low to capture from the St Louis area in Missouri."

Equipment: SBIG ST-8300M CCD camera, Astro-Tech AT90EDT telescope.

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Email your pictures to us at hotshots@skyatnightmagazine.com or enter online.

2015 MY OBSERVING YEAR

Top amateur astronomers from the US and UK talk to **Will Gater** about their observing wishlists in the year ahead, plus our top picks for 2015

Next year many will be excitedly awaiting the arrival of darkness during the total eclipse in March, and later in the year the Moon gets in on the action with a total lunar eclipse in September. These are the stand-out astronomical events that will get everyone looking skyward. But we astronomers need more than that: we have an urge to observe that we would satisfy 365 days (or more accurately nights) per year if we could. We spoke to six of the most dedicated, passionate amateur astronomers out there and asked them what their intentions were in the 12 months ahead. Read on to discover how they plan on fulfilling their astronomical aspirations in 2015 and for our own recommendations of great observing sights in the seasons ahead. ▸

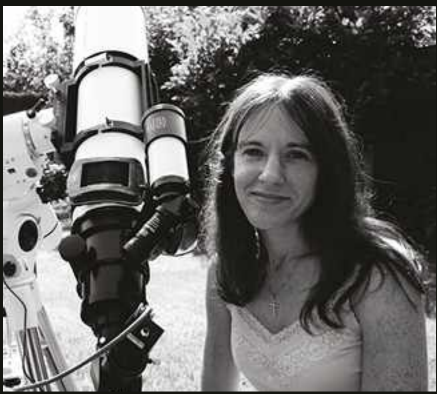
PAUL WHITFIELD, ALEXANDRA HART, © NATIONAL GEOGRAPHIC IMAGE COLLECTION/ALAMY

ABOUT THE WRITER

Will Gater is an astronomer, science writer and author of several popular astronomy books, including *The Practical Astronomer*. He tweets as @willgater.

ALEXANDRA **HART**

Solar imager and Astronomy Photographer of the Year 2014 'Our Solar System' winner

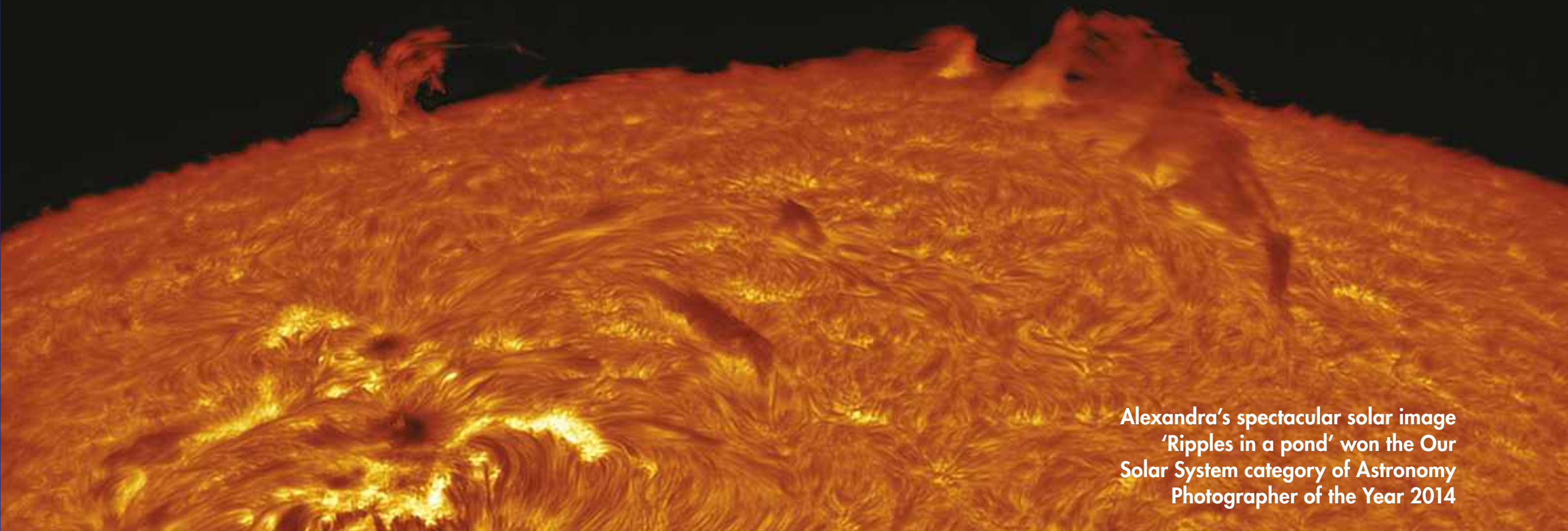


I am obsessed with imaging the Sun, although at night I do enjoy staring at the stars and any planets and taking wide-angle landscape photos of them – but I am far from being any good at it!

My first love is the Sun: what I enjoy most is that it is so dynamic. It is never the same in appearance from one moment to the next and there is always something to study, even on a quiet day.

What I would like to see most this year – and these have been on my bucket list since I started solar observing – are a white-light flare and an X-class flare in hydrogen-alpha. I'd also love to get the chance of make animations of post-flare loops or a large prominence lift-off event.

I think the highlight in everyone's diary will be 20 March, though, when we get to witness a partial solar eclipse. Where I live, the Sun will be up to 90 per cent per cent covered by the Moon and should be an amazing sight for anyone with solar eclipse glasses. I'm just worried it will be cloudy as there won't be another where so much of the Sun is covered for a long time.



Alexandra's spectacular solar image 'Ripples in a pond' won the Our Solar System category of Astronomy Photographer of the Year 2014

JON **SHANKLIN**

Director of the British Astronomical Association's comet section

I have a wide range of interests – solar observations, variable stars, comets and meteors. All of my observations are visual, mostly using binoculars for the variables and comets, a small telescope for the Sun and just my eyes for meteors. Over the past year I've observed half-a-dozen or so comets. The one that generated the most excitement was of course C/2012 S1 ISON, and though it didn't get as bright as many had hoped for I did get a nice glimpse of it and its short tail just prior to perihelion.

One of my tasks as director of the British Astronomical Association and Society for Popular Astronomy comet sections is looking forward and predicting what comets will come within easy range. It's a bit of a lottery. Unusually, there are three in the frame for easy binocular viewing in 2015. There is a chance that C/2013 US10 Catalina might be a naked-eye object in late November. C/2014 Q1 PANSTARRS may be good in the southern hemisphere and C/2014 Q2 Lovejoy could be a nice binocular object at the start of the year.

Three comets could become good binocular targets in 2015

SEASONAL SIGHTS WINTER

14 JANUARY 2015
The bright winter constellations of Orion, Gemini and Auriga are high in the south at 10pm.

16 JANUARY 2015
Saturn sits a little over 2.5° from the crescent Moon in the predawn sky.


Magnificent Saturn will be close to the crescent Moon on 16 January

22 JANUARY 2015
Venus and Mars are joined by a thin crescent Moon low in the west after sunset.

6 FEBRUARY 2015
The giant planet Jupiter is at opposition tonight in the constellation of Cancer, the Crab.

14 FEBRUARY 2015
The Orion Nebula is due south at 8pm; it's a superb object for a small telescope.

21 FEBRUARY 2015
The planets Mars and Venus are just over 28 arcminutes from one another tonight.

22 FEBRUARY 2015
The constellations Leo and Virgo are high in the south at 2am, providing a good opportunity for galaxy hunting.

2 DECEMBER 2015
The Andromeda Galaxy, M31, is high in the south at a sociable 8pm.


The Andromeda Galaxy will be well placed in December

8 DECEMBER 2015
The crescent Moon lines up with Venus, Mars and Jupiter in the southeast before dawn.

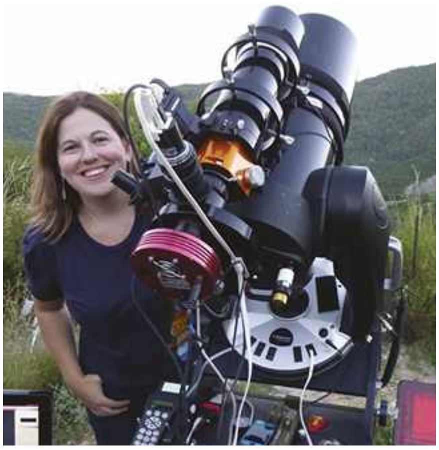
14 DECEMBER 2015
The Geminid meteor shower reaches its peak this evening. Look for meteors streaking from the head of the 'Twins'.

WILL GATER, THINKSTOCK X 5, ANNA MORRIS X 2, BILL LEATHERBARROW X 2


▲ Anna's shot of the Pac-Man Nebula reveals a staggering amount of detail


▲ Aim for less familiar targets – this is NGC 6559 – to take you out of your comfort zone

ANNA MORRIS
Deep-sky astrophotographer



"The objects that hold the greatest interest for me right now are nebulous regions, especially emission and dark nebulae. I'm also trying to find regions that aren't imaged that often in order to pull out as much detail as I can from them. Capturing dozens of hours of data to process is incredibly fun and fascinating to me.

It takes patience to image nebulae in narrowband well: they need to have enough data gathered on them to really show them off. So I'll spend multiple nights on a single target at a time with a single filter. You get to find out a lot about astrophotography by pushing out of your comfort zone when selecting targets.

In 2015 I'm planning on working on imaging more galaxies. I tend to focus on nebulae as they've always interested me more, but the more time I spend reading about galaxy formation and interactions within them, the more it makes me want to concentrate on imaging them than I have in the past. Having said that, I have also found time to collect enough data on some obscure parts of nebulosity that you don't typically see in images in order to really bring them out."

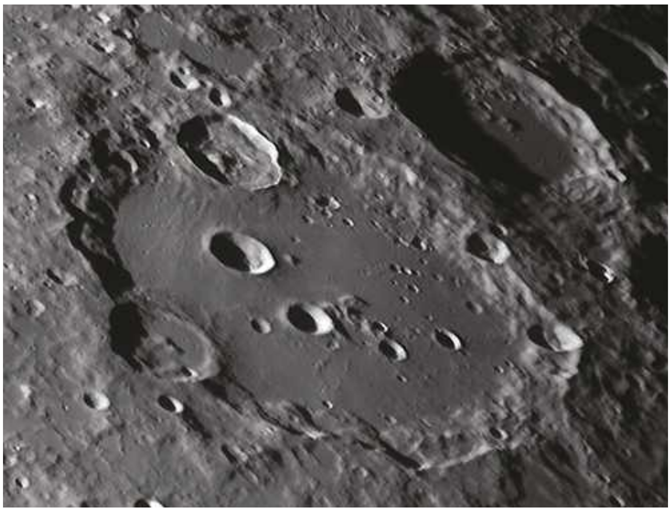
BILL LEATHERBARROW

Director of the British Astronomical Association's lunar section

"I've always been a keen observer of the Moon and planets, but especially the Moon. When I first started out in the 1960s I was a visual observer relying on pen and paper to depict the lunar and planetary surfaces, but now I have taken up high-resolution imaging with high-speed planetary cameras. Don't be put off observing the Moon by its familiarity in our skies, or by the complaints of deep-sky observers that its light drowns out faint objects! It is a fantastic telescopic object that rewards patient observation.

This year should be good for eclipses visible from the UK too. The solar eclipse of 20 March will be total from the Faroe Islands and Svalbard, but it will also be an impressively large partial eclipse from the British mainland. The total lunar eclipse on 28 September will be visible in its entirety from Britain.

But the most exciting event of the year, in my mind, will be the arrival of the New Horizons spacecraft at Pluto in July. I cannot wait to see the images returned from its flyby."



▲ Bill's beautiful shots of Crater Tycho (left) and Crater Clavius (right) show that the Moon can offer up as much intricacy as a nebula or galaxy

SEASONAL SIGHTS SPRING

The Beehive Cluster is one of the stand-out objects in Cancer

19 MARCH 2015
At 9pm tonight the beautiful open cluster M44 – also known as the Beehive Cluster – is due south.

20 MARCH 2015
This morning a spectacular total solar eclipse will be visible from Svalbard and the Faroe Islands; it's a good partial eclipse from the UK too.

22 MARCH 2015
The crescent Moon sits around 3.5° from Venus low in the west after sunset.

8 APRIL 2015
Why not use tonight to observe the beautiful double star Algieba in Leo, which is due south at 10.18pm.

11 APRIL 2015
Venus is roughly 2.5° away from the sparkling Pleiades cluster in Taurus this evening.

March's total solar eclipse is visible from the Faroe Islands

12 APRIL 2015
The Leo Triplet galaxies (M65, M66 and NGC 3628) are due south just after 11pm.

22 APRIL 2015
Star cluster Melotte 111 is high in the south at 11.30pm.

5 MAY 2015
Now is a good time to spot Mercury, low in the west after sunset.

12 MAY 2015
With the Moon mostly out of the way, tonight is a good time to go galaxy hunting in Virgo.

23 MAY 2015
Today Saturn is at opposition, meaning now is a great time to observe the Ringed Planet.

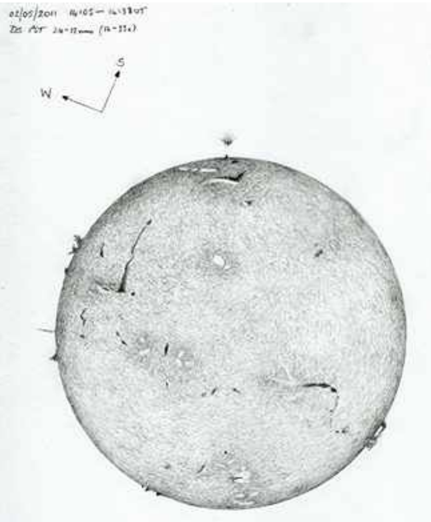
SALLY **RUSSELL**

Visual observer and astronomical sketcher

"My main interests in astronomy are observing and sketching the Moon, Sun and Mars. The Moon and Sun in particular provide ever-changing vistas – the fleeting nature of these views is the challenge that makes my fingers just itch to pick up a pencil and commit the views to paper!

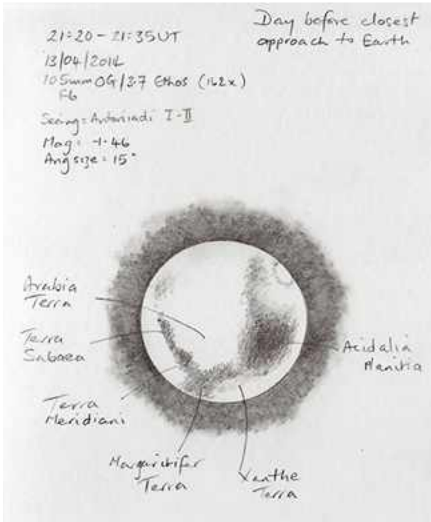
You don't need to be artistic – absolutely anyone can have a go at sketching what they observe. The equipment for getting started with sketching is cheap and simple – a couple of graphite pencils (the ones I use the most are 2B and 4B), a plastic eraser, and a small pad of medium weight cartridge paper. A red headtorch is useful too, for hands-free lighting to sketch by.

Jupiter will be very well placed for observing over the winter and into the early part of 2015. During this apparition there will be numerous satellite eclipse and occultation events, so I hope I'll get the chance to observe and record some of those. I invested in a fine double star atlas last year and would like to make good use of it in 2015. I've always been interested in them but simply haven't known where to look!"



▲ Sally's gorgeous sketch of the Sun in hydrogen-alpha, drawn on 2 May 2011

▲ Sally's rendering of Crater Gassendi from 20 June 2011 captures the starkness of the Moon



▲ Sally's sketch of Mars from 13 April 2014 shows many major dark albedo features

SEASONAL SIGHTS SUMMER

JUNE–EARLY AUGUST
Keep a look out for the beautiful glowing wisps of noctilucent clouds after sunset and before sunrise.

11 JUNE 2015
Showpiece globular cluster M13 in Hercules can be found due south at 12.30am this morning.

Noctilucent clouds are often described as 'eerie blue tendrils'

30 JUNE 2015
Tonight Jupiter and Venus are just over 21 arcminutes from one another, low in the west after sunset.

9 JULY 2015
The Lagoon and Trifid Nebulae, M8 and M20, are due south just before midnight on the 10th.

MID JULY
With new Moon on the 16th, now's the time to observe and image the stunning summer star fields of the Milky Way.

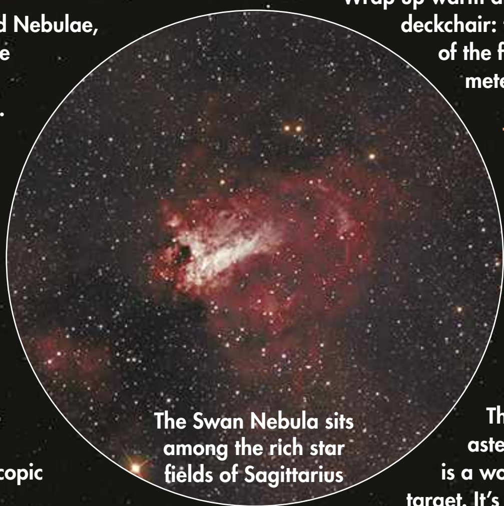
18 JULY 2015
The Swan Nebula, M17, is a lovely telescopic object in the south at around 11.30pm.

8 AUGUST 2015
At 10.48pm you'll find the sparkling stars of the Wild Duck Cluster, M11, due south.

13 AUGUST 2015
Wrap up warm and dig out that deckchair: today is the peak of the famous Perseid meteor shower.

14 AUGUST 2015
The Ring Nebula, M57, is high in the south at around 10.20pm; so is the quadruple star system of Epsilon Lyrae.

17 AUGUST 2015
The Coathanger asterism in Sagitta is a wonderful binocular target. It's due south at around 10.45pm tonight.



The Swan Nebula sits among the rich star fields of Sagittarius

SALLY RUSSELL X 3, WILL GATER X 2, DAMIAN PEACH X 2, THINKSTOCK X 4

Damian's latest shot of Jupiter, taken on 28 October 2014

DAMIAN PEACH

Planetary imager and overall Astronomy Photographer of the Year 2011

"My prime interests are the planets and comets. I'm a big fan of these dynamic objects – things that can change in appearance on rapid time scales: like the ever-changing atmosphere of Jupiter, or the appearance of an icy comet as it moves across the sky.

The planets in particular are great objects to try your hand at photographing. It needn't cost that much: a webcam-type camera hooked up to a laptop will take good images and is an affordable way to start. Objects like Jupiter are easy to locate too, and even small telescopes will show detail on its disc.

Last year was a busy one for me in terms of imaging. Jupiter and Mars were prominent targets during the first half of 2014 and I put in a brief spell on Saturn in late spring. There have also been several interesting comets I've been following. In 2015, Jupiter is well placed during the early half of the year so I'll be imaging that when I can. Also, a few comets look like they will become nice sights in our skies, such as C/2013 US10 Catalina. I'm still debating on what to do for the solar eclipse in March, the weather prospects along the path of totality make it a tricky decision."

Damian's stunning shot of C/2012 S1 ISON, taken on 15 November 2013

SEASONAL SIGHTS AUTUMN

Early September offers a glimpse into the heart of our Galaxy

EARLY SEPTEMBER
The rich Milky Way star fields that wind through the constellation of Cygnus are almost directly overhead at around 10pm.

14 SEPTEMBER 2015
Albireo in Cygnus, arguably the finest double star in the autumn skies, is high in the south around 9pm.

19 SEPTEMBER 2015
Globular cluster M71, in the constellation of Sagitta, is due south at around 9.05pm.

28 SEPTEMBER 2015
The UK will be treated to a total lunar eclipse in the early hours of this morning.

29 SEPTEMBER 2015
Tonight the asteroid Vesta will be at opposition in Cetus, though the bright gibbous Moon will be nearby.

November's lunar eclipse will be total across the UK

12 OCTOBER 2015
Turn your telescope towards the outer Solar System – the ice giant Uranus is at opposition today.

18 OCTOBER 2015
The Andromeda and Triangulum Galaxies, M31 and M33, are high in the south at around 12.30am.

7 NOVEMBER 2015
Jupiter, Mars, Venus and the crescent Moon come together for a beautiful gathering in the predawn sky.

17-18 NOVEMBER 2015
Tonight's a good time to look out for shooting stars as it's the peak of the Leonid meteor shower.

19 NOVEMBER 2015
The Pleiades star cluster, M45 in Taurus, is due south at midnight.

Stargazing LIVE 2015

THE LATEST NEWS

Assistant producer **Keaton Stone** lifts the lid on series five, coming to your living room in March

NASA/JPL-CALTECH X 3, THINKSTOCK, BBC X 2, SIMON MACKIE

Please do not adjust your television set! There is no need to panic: the *Radio Times* hasn't made an error in its listings and overlooked the late Christmas present that UK astronomy fans have gotten used to receiving over the past few years. Rather, the next series of *Stargazing LIVE* will be breaking with tradition and airing in March instead of January in 2015.

While this may please those who regularly petition us to broadcast later in the year so as to maximise the chances of success with the weather (a common sight in the studio gallery over the past four series has been the team on their knees praying for clear skies to any passing Cloud Gods within earshot just before transmission), we've made the change for a different reason: we are aiming to bring something pretty special to your screens.

Now what, you might ask, could possibly top the unprecedented live screening of the aurora borealis from a plane, as we did for series four back in January 2014? Well, we think that the greatest of all nature's spectacles – a total solar eclipse – may just prove to be our ace in the hole.

For series five we are venturing north to the Faroe Islands in order to try and capture the sure-to-be breathtaking display put on by two of our celestial friends. However, being so far north we are perhaps testing our luck for the chance of a clear view of totality without being clouded out; which is why we're once again dusting off our trusty plane (Stargazer One?) and taking to the skies in attempt to bring this incredible event to you live without the need for you to freeze in the Arctic Circle! Wish us luck...

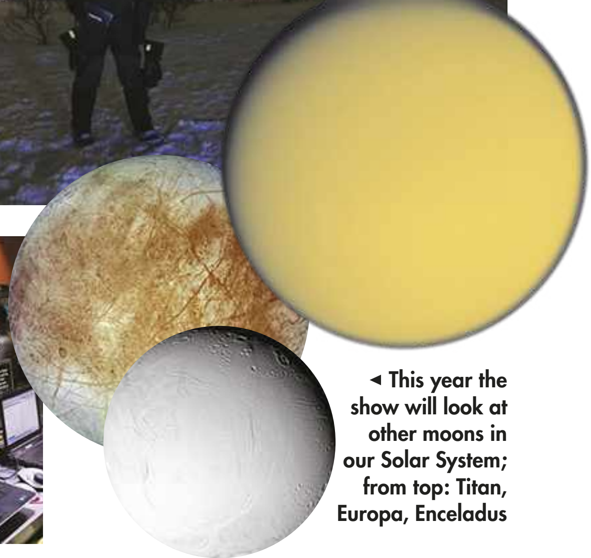
Breakfast broadcast

By its very nature, you can only see a solar eclipse when the Sun is up, which is pretty inconsiderate for our evening schedules. So to bring you the event live we will have an extra show that will go out on the morning of Friday 20 March, probably linking straight from *BBC Breakfast*.

Star guests will join Dara Ó Briain and Brian Cox for the new series of *Stargazing LIVE*

Liz Bonnin will be in the field once more – possibly aboard 'Stargazer One'

The team will be broadcasting a special breakfast episode



◂ This year the show will look at other moons in our Solar System; from top: Titan, Europa, Enceladus

As the eclipse is our main focus this time around we'll be highlighting the orbital mechanics and 'celestial ballet' of the cosmos, which through various coincidences of alignment allows for such sensational displays to occur. But we'll also be dedicating an episode to some of the actual astronomical bodies that are equally integral.

We'll be taking an in-depth look at our star to find out why it is so special for us here on Earth; and we'll also be taking a trip across the Galaxy to investigate other stars and hear how the latest space missions are helping us to learn more about these distant cosmic furnaces. It's early days and things are always liable to change, but tentatively we're going to look into the lives of stars, from their dusty beginnings through protostar-hood and into middle age like our Sun is now, then on to some of the spectacular ways that stars eventually die.

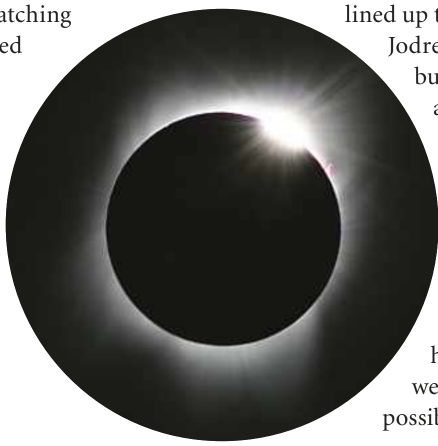
We also plan on examining supernovae a bit closer as well as running a citizen science campaign alongside the series, which people watching at home can get involved in. This time around we want the public's help in hopefully identifying a record amount of these stellar fireworks.

Moon rakers

The other major ingredient you need in a solar eclipse is the Moon, of course. We have visited our closest neighbour a number of times over *Stargazing LIVE*'s lifetime, so we're keen to explore some of the other strange and fantastic bodies that orbit other planets. We're interested in Jupiter's Galilean satellites as well as Saturn's moon Titan – the only other moon we've ever landed on, sometimes described as 'Earth in the freezer' due to it having an atmosphere and weather cycle. Europa and Enceladus are also fascinating, both being particularly strong candidates for being the home of potential life elsewhere in the Universe.

As ever then we aim to treat viewers to a star guest and without giving anything away we have someone VERY special lined up to join us in March at Jodrell Bank... apologies, but that's all I'm allowed to say!

What I can say is that series five is shaping up to be one of the most memorable yet – which will of course only present us with a headache later on when we wonder how we can possibly top it. But let's not worry about that for now. Instead, in March let us once again come together to turn on, tune in and look up! Ⓢ



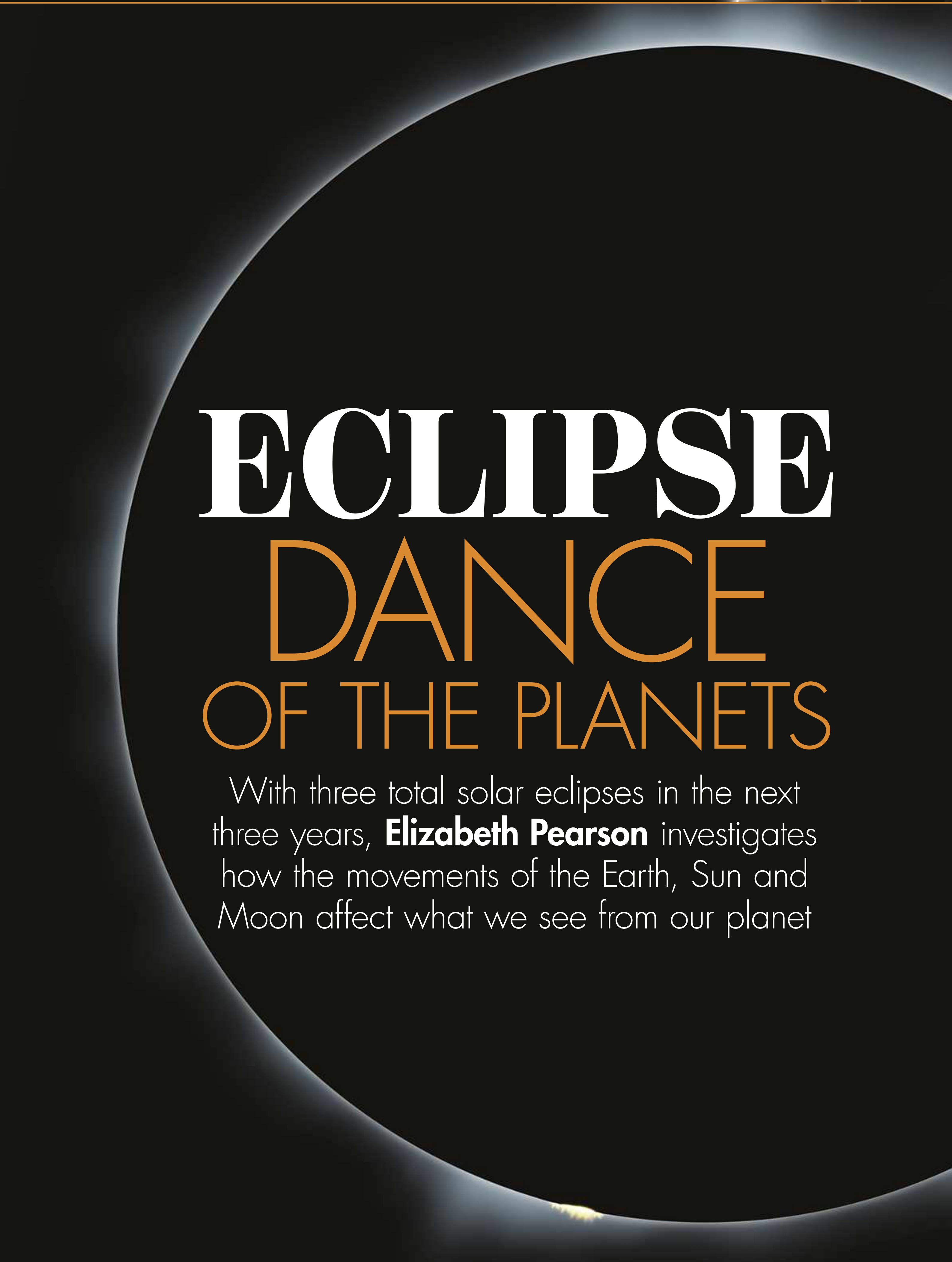
▴ The team hope the March eclipse will top the live aurora from last year's show

BBC TWO

***Stargazing LIVE* will be broadcast on BBC Two on 18, 19 and 20 March 2015. For updates and show times follow @BBCStargazing.**

ABOUT THE WRITER

Keaton Stone is a space enthusiast, and assistant producer for *Stargazing LIVE* and other BBC science shows. Follow him on Twitter: @Keaton_S



ECLIPSE DANCE OF THE PLANETS

With three total solar eclipses in the next three years, **Elizabeth Pearson** investigates how the movements of the Earth, Sun and Moon affect what we see from our planet

ABOUT THE WRITER

Elizabeth Pearson is *BBC Sky at Night Magazine*'s staff writer, specialising in space science. She gained her PhD in extragalactic astronomy at Cardiff University.

This March, a creeping darkness will sweep across part of the northern hemisphere. But there's no need to worry. As the sky falls dark you can rest assured that it had been predicted decades ago, as has every other passing of our planet into the shadow of our Moon for the next millennium.

In March this year the path of a total solar eclipse will pass well north of the UK. The shadow of the Moon will eventually fall on the Faroe Islands, before its path continues north. Finally, it will fall on frozen Svalbard, only recently emerged from the unending night of Arctic winter.

The beautiful Faroe Islands will see a total solar eclipse in March

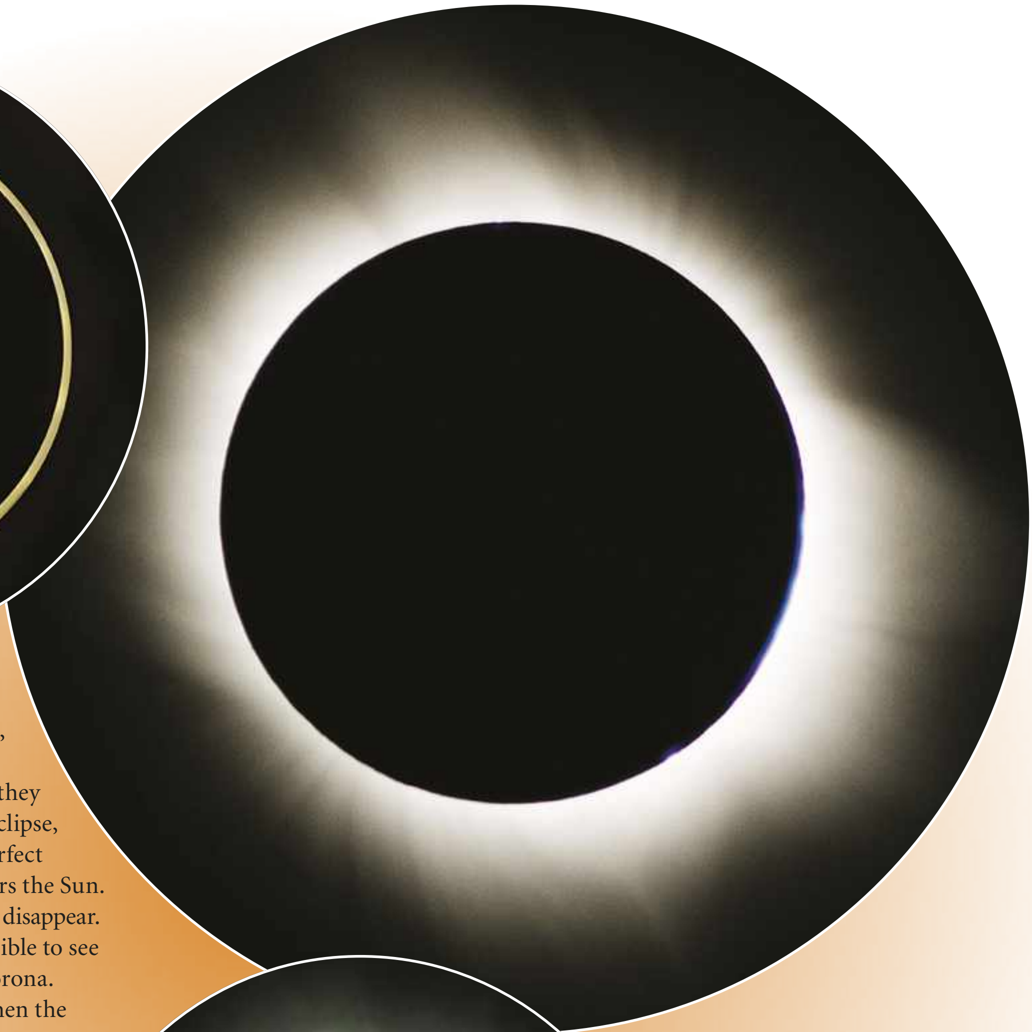
"A total solar eclipse of the Sun is just the most spectacular astronomical phenomenon that you can see with your naked eye," says Fred Espenak, scientist emeritus at NASA's Goddard Space Flight Center. "The experience of having that shadow go over me – of witnessing the environment go into this eerie twilight and the stark beauty of the corona – was just overwhelming."

For some of those heading to the Faroes, it will be a chance to experience totality for the first time. But for dedicated eclipse chasers, this will be the start of a rare run of the solar phenomenon. The next three years we will be an age of totality, with every year seeing a total eclipse somewhere on the Earth.

A tale of two seasons

With so many people from all over the globe racing to catch the phenomena, you would be forgiven for thinking that an eclipse is a rare sight. In a way, it is, but that's not the whole story. While a total eclipse being visible from a particular place on the Earth is rare, there are actually two 'eclipse seasons' each year, consisting of at least one solar and one lunar eclipse. However, this doesn't mean that there are only two total solar eclipses every year. There can ▸

THINKSTOCK, © CULTURA RM/ALAMY



▸ be as many as seven eclipses, and due to the orbital fine-tuning of the Solar System, they may not all be 'total'.

When most people think of an eclipse, they think of totality, the apex of a total solar eclipse, where the Sun, Moon and Earth are in perfect alignment and the Moon completely covers the Sun. Even here, the Sun's light doesn't completely disappear. With the central brightness gone, it's possible to see the beautiful arcing curves of the Sun's corona.

A second kind of eclipse can happen when the Sun, Moon and Earth are in perfect alignment: an annular eclipse. Normally the Moon and Sun appear to be the same size on the sky, which is why the shadow of one can completely cover the other. However the Moon's orbit around the Earth is not a perfect circle, which causes the Moon's apparent size to change over the course of each month by 14 per cent. When the Moon appears smallest it no longer fills the Sun's disc. When eclipses happen during this time, they are annular instead of total. A thin ring of fire remains visible around the edge of the Moon's shadow, and this can be just as beautiful as totality.

Away from totality

Both annular and total eclipses are classed as 'central eclipses'. But there is also a blend of the two, called a hybrid. These are the rarest of all eclipses, making up only a five per cent of these events. They only occur when the movement of the three bodies in their orbits causes the Moon to transition from covering the Sun entirely to being too small just as the lunar shadow crosses Earth. Watching this eclipse, you would see it change from a total to an annular, or vice versa.

Even if there is a central eclipse, totality can only be seen along a narrow corridor known as the path of totality. As you travel farther from this central path a smaller proportion of the Sun is covered by the Moon, gifting viewers in these areas a partial eclipse. During the Faroe Island's total eclipse the Sun won't be totally obscured for those of us in the UK, but there will be at least an 80 per cent partial eclipse everywhere in the British Isles.

In every solar eclipse some swathe of Earth's surface will see the Sun partially blocked, however there some eclipses during which the darker umbral shadow misses the Earth completely, meaning there is no totality anywhere on the planet. On 23 October 2014 there was a partial eclipse that could be seen from North America, but in order to see totality you would have had to have been several hundred kilometres above the North Pole.

While partial and annular eclipses may lack the mysterious allure of totality, they are still beautiful to behold, though a bit more caution is needed to view them safely. If only one per cent of the light from the Sun reached your eyes your vision would be damaged, so these events need to be viewed either indirectly (eg, projected onto cardboard) or through

Eclipses appear in various guises: top left, annular; top right, total; and above, partial

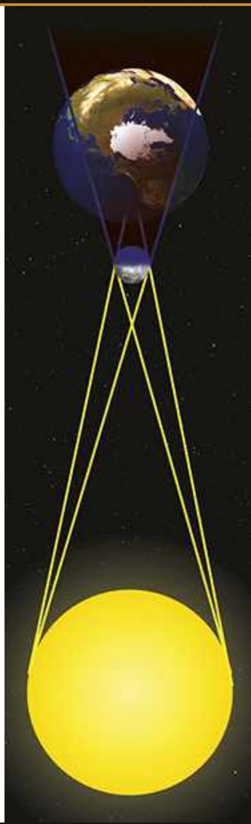
THINKSTOCK X 3, ALAMY, ILLUSTRATIONS BY STEVE MARSH

special filters. What you don't get with these eclipses is the dramatic dimming of the sky to a false twilight. This occurs only when a large portion of the Sun is covered and the event is viewed from, or very close to, the path of totality.

Crossing points

But why do eclipses only happen twice a year during the 34-day window of an eclipse season? The Moon's orbit around the Earth is inclined at 5.3° to the ecliptic, the plane in which the Earth orbits the Sun. That means that even if the Earth, Moon and Sun are aligned in a straight line as seen from above (known as a 'syzygy', shown on the right), the Moon may be too high above or too low below the orbital plane to block out the Sun's light. If this wasn't the case then there would be a total solar eclipse visible 23.5° either side of the equator every new Moon. As it is, for an eclipse to occur the Moon has to be at the point in its orbit called a lunar node – where it cuts across the ecliptic – at the time of the new Moon.

This happens at intervals of slightly less than six months. At this time the lunar nodes line up with the Sun, and this lasts for 34 days before slipping out of alignment again. During this window there will always be two eclipses – a solar eclipse at new Moon, then a lunar eclipse at full Moon. Sometimes, if the timings are right, a third eclipse can sneak in as well. This means that there will always be four eclipses a year, but there can be as many as seven – though the last time this happened was in 1982, and it won't happen again until 2038.



◂ **Even if the Sun, Moon and Earth appear in line from above (a syzygy), they may not line up in the orbital plane – so the Moon's shadow will miss the Earth and there is no eclipse**

As the motions of the planets are so reliable, scientists and astronomers have been predicting the dates of eclipses for centuries, or at least attempting to. The Antikythera mechanism, a 2,100-year-old ancient Greek 'computer' recovered from a wreck in 1900, is believed to be an early device for predicting the motions of the planets and, it appears, eclipses.

"They couldn't calculate which city would see an eclipse, but they could certainly predict when an eclipse might be likely to happen on a given day," says Espenak.

A veteran of over 25 eclipses himself, Espenak has been key in testing the Antikythera mechanism's ▸

THE SAROS **CYCLE**

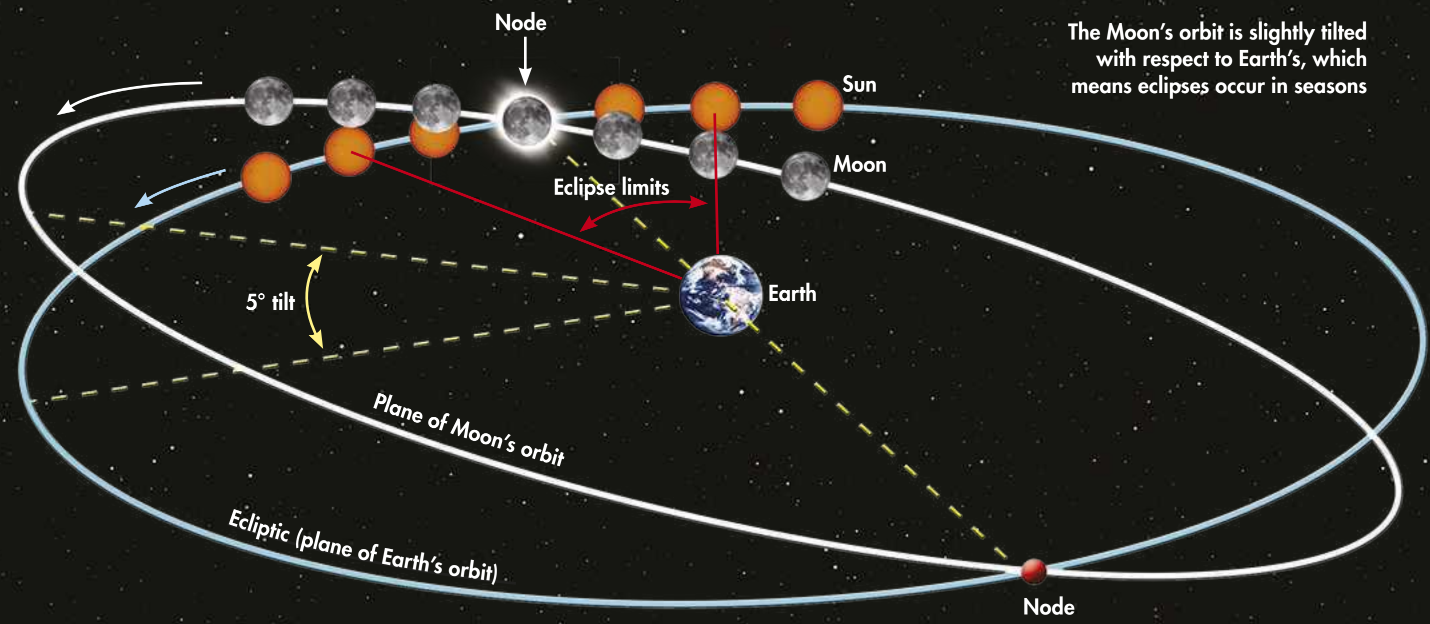
It takes 27.2 days for the Moon to complete one orbit around Earth, a period known as the draconic month. In this time it crosses the plane of the ecliptic twice due to its inclined path. However, as Earth is also moving around the Sun, it takes a little bit longer for the Moon to reach the same phase. This is why there are 29.5 days between full Moons, a period known as a synodic month. This means that for the Sun, Moon and Earth to return to a similar geometry it takes 18 years, 10 days and about eight hours. This period is known as a saros cycle, or saros, and is useful for predicting when eclipses will happen. Solar eclipses recur one saros apart, but at different places on the Earth.

"The cycles can mismatch by a handful of hours," says Espenak. "If you go over hundreds of years the alignment slowly drifts away."

As the alignment drifts, it causes the position of the eclipse to move across the globe until the shadow no longer falls on Earth's surface, signifying the end of that particular saros. However another cycle will start up to take its place, leading to dozens of them overlapping.

"A saros only goes on for around 12-13 centuries," says Espenak. "They start out as partial eclipses at one of the poles, and then you get a series of total eclipses before eventually you find the eclipses drift to the opposite pole and become partial again. Then the magnitude of the eclipse becomes progressively smaller until no eclipse takes place at that node."

There are currently 41 active cycles. The last new saros began in May 2013, but the 'eclipse' that heralded it wasn't even viewable to the naked eye, covering only two per cent of the lunar disc. It can take the cycles a long time to mature, and the new saros won't provide a total eclipse for over 500 years.



The Moon's orbit is slightly tilted with respect to Earth's, which means eclipses occur in seasons

▲ The 2,100-year-old Antikythera mechanism may have been used to calculate eclipse dates

THINKSTOCK, © ZUMA PRESS, INC./ALAMY ILLUSTRATIONS BY PAUL WOOTTON

▸ precision, as well as creating a modern catalogue using a battery of computer programs that not only predicts future eclipses, but also backtracks them to over 2,000 BC. "I wanted to look to the past because it is of interest to historians and archaeologists," he says. "Over the years I've written many eclipse prediction programs, each one does a different aspect of eclipse predicting."

The programs have created 11,898 eclipse predictions spanning a period from 2,000 BC to 3,000 AD. However, the further predictions get from the current day, the less accurate they become. "Going back it gets tricky because Earth's rotational period slows down," says Espenak. "This is due to the exchange of momentum between Earth and Moon through frictional drag. It happens at an unpredictable rate so it's difficult to predict the exact rotation of the Earth as you go into the past or into the future."

With at least two eclipses each year, why do people travel thousands of kilometres across the globe, chartering boats and private planes, to catch these fleeting phenomena?

Though the path of an eclipse can be thousands of kilometres long, they are also very narrow. While a partial eclipse might be seen in a corridor spanning several countries, the path of totality is often less than 100km wide. Most places on the Earth will be able to see a partial eclipse every decade or so, but the time between central eclipses can be much longer, potentially centuries.

The last total solar eclipse that was visible from the mainland UK happened in 1999. Sixteen years ago the path of totality was limited to Devon and Cornwall, and cloud meant that many missed this once in a lifetime show. Those waiting for another chance to see a total eclipse from the UK won't have to travel far, as the next path of totality to cross over Great Britain will once again cross Devon and Cornwall. We have a bit of a wait on our hands though, as it won't happen until 2090.

There's a better chance of seeing totality by travelling overseas, and 20 March 2015 is just the first opportunity to come over the next few years in the age of totality. On 9 March 2016 Indonesia will be plunged into darkness by the Moon, while on 21 August 2017 a shadowy path 2,500km long will cut across mainland US. Ⓢ

THREE TIMES **TOTALITY: 2015-2017**

20 March 2015 *max duration 2m 46.9s*

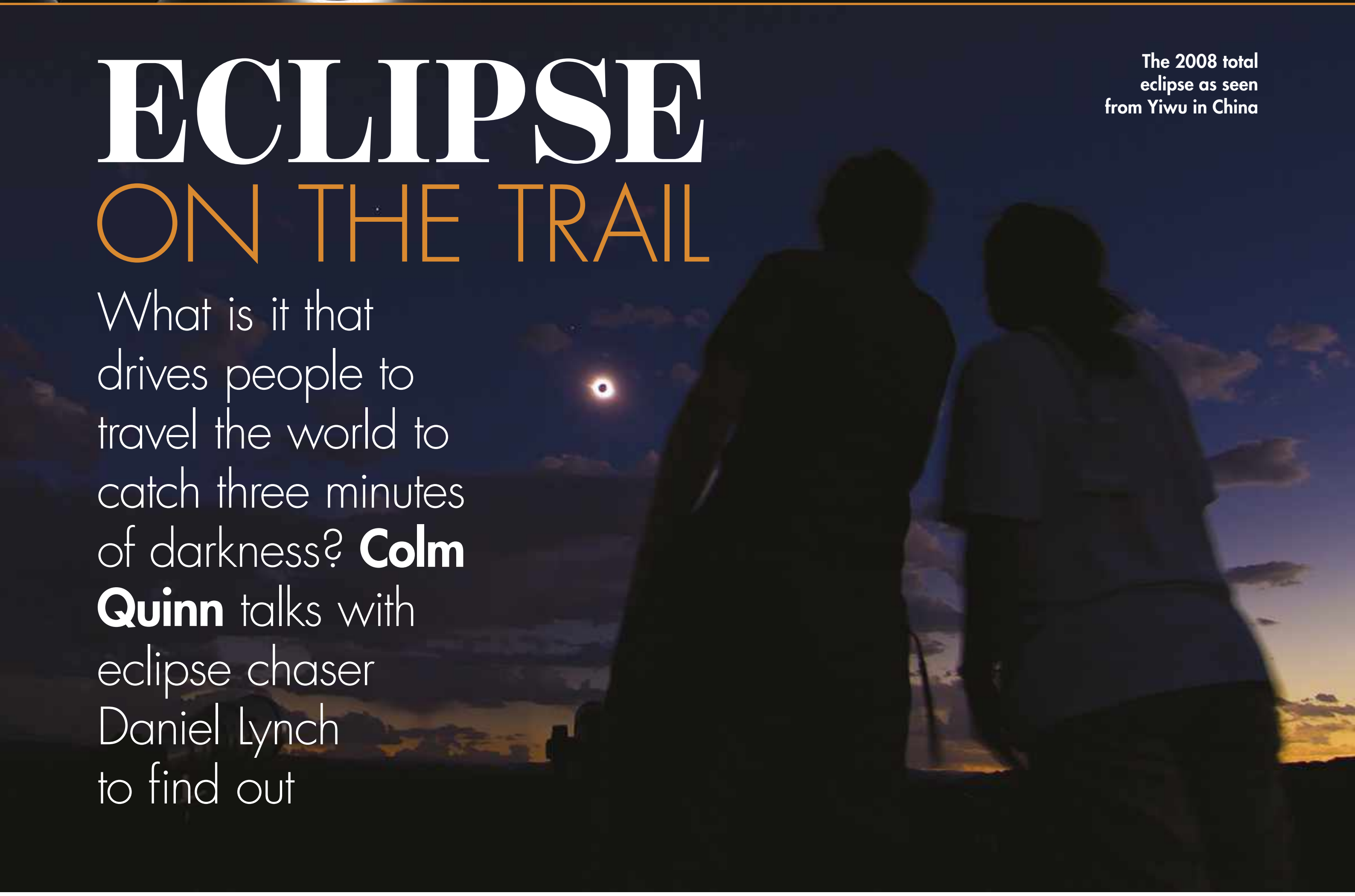
This year's eclipse will only be visible on land from the Faroe Islands and Svalbard. However, at this time of year the chance of cloud covering the view of totality is fairly high, though cloud will darken false twilight.

9 March 2016 *max duration 4m 09.4s*

Most of this eclipse passes across the Pacific Ocean, though a portion of the path travels over Indonesia giving eclipse chasers an exotic destination to catch the sight from. Again, there is a risk of clouds at this time of year.

21 August 2017 *max duration 2m 40.2s*

The North American eclipse in 2017 may be the best opportunity to see a total solar eclipse in the next few years. It passes across the whole of continental US from South Carolina to Oregon.



ECLIPSE ON THE TRAIL

The 2008 total eclipse as seen from Yiwu in China

What is it that drives people to travel the world to catch three minutes of darkness? **Colm Quinn** talks with eclipse chaser Daniel Lynch to find out

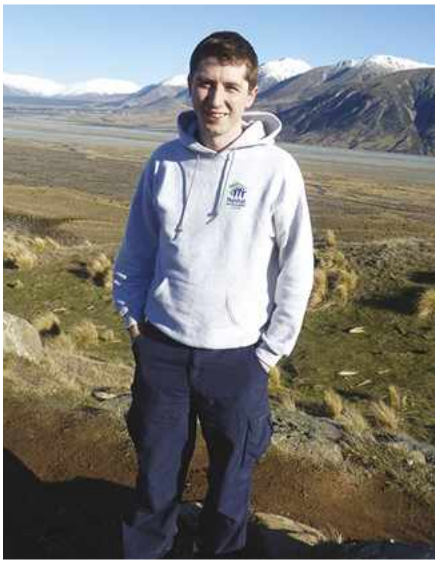
There is an ancient Chinese myth that a solar eclipse was a dragon trying to eat the Sun, so the people fired arrows at it to drive it away. And they had a 100 per cent success rate, as each time the cowardly dragon retreated and the warriors patted each other on the back for a job well done.

Thirty-year-old maths teacher Daniel Lynch almost has a perfect score with eclipses too. He's part of the small but enthusiastic group of people who call themselves eclipse chasers; people who, year after year, take planes, freight tankers or anything else which will get them on the right spot of land, sea or air to view these fleeting phenomena.

His most recent viewing was on 3 November 2013 off the coast of Bermuda. The path of the eclipse wasn't going to be making landfall on the island, so he and 11 other eclipse chasers chartered a plane to fly them out into the Atlantic where it could be seen.

Lynch sits in his classroom in Gonzaga College in Dublin, explaining why this eclipse was such a unique experience. "Normally the path of totality is maybe 200km across: you just stick yourself anywhere in the 200km and you get to see it. But in this case it was about 1km across.

DANIEL LYNCH X 2



▲ Schoolteacher Daniel Lynch has not missed a total solar eclipse since 1999

"This particular eclipse was difficult and unique. There was only a very small shadow and there was no way to fly along the eclipse path and be able to see it outside the window." Faced with this problem Lynch and his fellow eclipse chasers came up with another way to see it.

"The only way was to fly at right angles, trying to hit it perpendicularly. This was a huge task on this particular eclipse. The shadow normally moves at around 2,000km/h, but this time around it was going to be moving at 8,000km/h. It is as if you were trying to shoot a bullet against another bullet, side on."

A faltering start

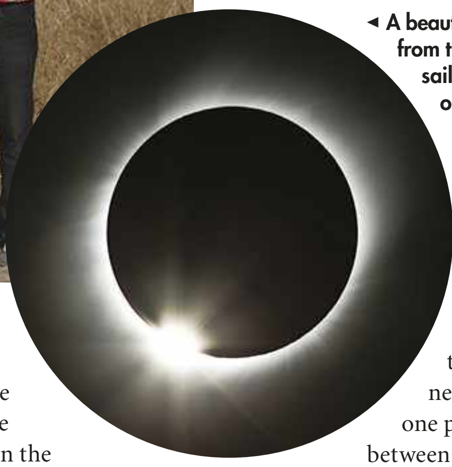
Lynch's interest in eclipses was piqued when he saw a lunar eclipse as a young child. Over the years his interest would grow and when, as a 15-year-old, the 1999 total solar eclipse was going to cross Europe, he was determined to see it. Deciding against Ireland because the eclipse wasn't going to be total, and England because of the chance of clouds, he went to Germany. Where it lashed rain.

"I was not as disappointed as I thought I would be. It was still impressive in that it went dark and the temperature dropped, but I couldn't help thinking that the same effect could be had by stepping into my wardrobe."

Seeing pictures of the event on television made him even more determined to see ▸

▲ Lynch (second from left) and the group from Gonzaga College who travelled to Australia for the 13 November 2012 total eclipse

Totality approaches at the solar eclipse in Australia on 13 November 2012



◄ A beautiful diamond ring seen from the ship Costa Classica, sailing close to Iwo Jima on 22 July 2009

► one in the flesh. So Lynch researched when the next one was happening and two years later, in Zimbabwe, he finally got to see his first total solar eclipse.

"It was just an incredible view. It's so difficult to explain to someone what it's like seeing a total solar eclipse. Words don't do it justice. It looked like there was an incredible vortex up in the sky. There was this black hole where the Sun should have been."

After that he was hooked and has scrimped and saved his money to be able to see as many as possible. He's not the only one with this particular hobby, however. Eclipse chasers are spread out all over the world, but when an eclipse comes around most can be found along that narrow path wherever the shadow slices through.

Lynch has a good record with eclipse viewing – the only one he has missed in the past 15 years was his first one back in 1999. But he has come close to missing a couple because of cloud. One in the Gobi Desert in China in 2008 sticks out in his mind: "The government set up a viewing position and you weren't allowed move from it. Ten minutes before the eclipse, this one big horrible cloud just moved in." Then he saw something remarkable. "With 60 seconds to go we got what looked like a pretty miraculous dissipation of the cloud."

The past lives on

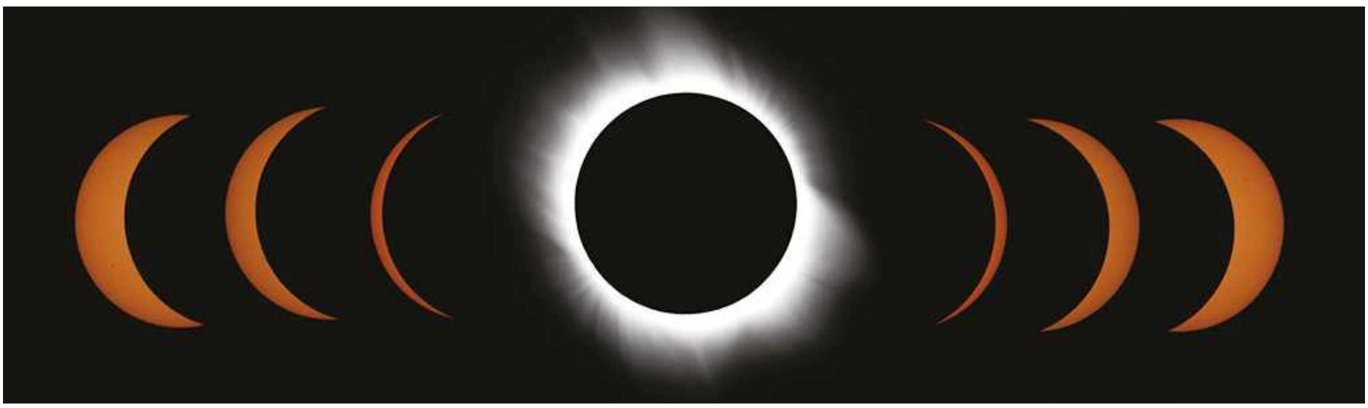
He only found out in Bermuda what really happened in China. In a modern-day scientific interpretation of the ancient practice of firing arrows into the sky during eclipses, the authorities shot two chemical rockets into the cloud, dissipating it allowing the eclipse chasers a clear view.

If you're inspired to view a total eclipse, the path of the next relatively close one passes off the coast between Britain and Iceland in March 2015. It can be seen from land in the Faroe Islands or Svalbard, or from a cruise ship or plane.

Lynch believes that the August 2017 eclipse in the US might be easier to see. It passes across the entire country and takes place during the summer. He will be there of course – Lynch is adamant that each eclipse is different. Saving for years to see something that lasts only a few seconds is, in his view, definitely worth it. Ⓢ

ABOUT THE WRITER

Colm Quinn is a feature writer from the Republic of Ireland covering science, music, culture and arts. He tweets from @cqbkcp.



DANIEL LYNCH X 4

▲ A composite sequence showing the Moon gradually masking the Sun during the total eclipse seen in Libya on 29 March 2006

PLUS

Stephen Tonkin's

BINOCULAR TOUR

Turn to page 58 for six of this month's best binocular sights

The Sky Guide January

The orbits of Jupiter's four Galilean satellites are tilted in a way that allows us to see them interact with one another. On the morning of the 24th there's a particularly rare sight: three moon shadows and two moons can be seen crossing the planet's disc at the same time.

PETE LAWRENCE

Written by Pete Lawrence

Pete Lawrence is an expert astronomer and astrophotographer with a particular interest in digital imaging. As well as writing *The Sky Guide*, he appears on *The Sky at Night* each month on BBC Four.

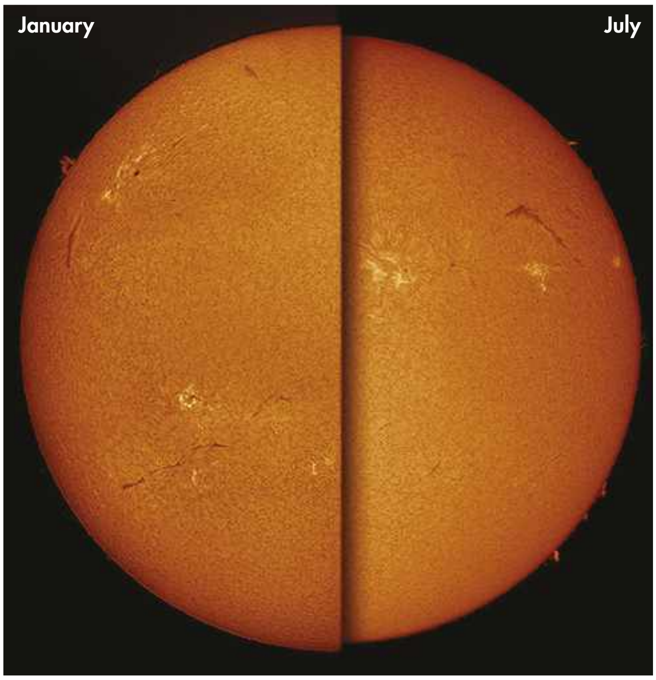
Highlights

Your guide to the night sky this month

This icon indicates a good photo opportunity

3 SATURDAY
The annual Quadrantids meteor shower peaks around 18:00 UT. Unfortunately, the Moon is near full and will rather spoil the show.

4 SUNDAY ▶
It might not feel much like it, but today the Earth is at its closest to the Sun for the year. This point in its orbit, known as perihelion, occurs at 06:36 UT; at this time our separation from the Sun will be 147,096,204km. The Sun's apparent diameter is at its largest for the year at this time.



8 THURSDAY
The 91%-lit waning gibbous Moon lies 5.5° south of mag. –2.3 Jupiter in the early hours.

Variable star Algol (Beta (β) Persei) reaches minimum brightness at 01:54 UT.

13 TUESDAY ▶
Look for the last quarter Moon just before dawn; the bright star 3.5° to the southeast is mag. +1.0 Spica (Alpha (α) Virginis).

Variable star Algol (Beta (β) Persei) reaches minimum brightness at 19:36 UT.

16 FRIDAY
The 22%-lit waning crescent Moon lies 3° west of mag. +0.9 Saturn this morning. Catch the pair at 05:00 UT, low in the southeast.

17 SATURDAY
Lunar libration is favourable for a view of Mare Orientale. The Moon is low in the southeast before dawn.

20 TUESDAY
Orion is well placed around 21:30 UT. With the Moon out of the way, this is a great time to investigate this beautiful constellation. The Orion Nebula, M42, is an obvious target, but M43, M78 and NGC 1977 are well worth hunting down too.

21 WEDNESDAY ▶
Look to the southwest just after sunset: mag. –3.8 Venus shines away in the evening twilight. A slim, 1%-lit waxing crescent Moon lies 7.75° to the right of Venus, while mag. +0.6 Mercury is just 2° below and left of the Moon's centre. See page 51.

24 SATURDAY
Definitely one not to miss, the shadows of three Galilean moons can be seen crossing Jupiter's disc between 06:28 UT and 06:53 UT. See page 50.

28 WEDNESDAY
Saturn is 58-arcminutes north of mag. +2.6 Acrab (Beta (β) Scorpii).

Variable star Algol (Beta (β) Persei) reaches minimum brightness at 03:36 UT

PETE LAWRENCE X 7

5 **MONDAY ▶**
Eclipsing binary star Algol (Beta (β) Persei) is well placed and drops to its minimum brightness at 05:06 UT. Algol has a precise cycle of variability lasting two days 20 hours and 49 minutes. During this time the star dips from mag. +2.1 to. +3.4, with minimum brightness lasting for 9.6 hours.

10 **SATURDAY**
Mercury is 0.6° west of Venus at 17:00 UT. Both planets (mag. –0.7 and –3.8 respectively) are visible low in the southwest at this time.

Variable star Algol (Beta (β) Persei) reaches minimum brightness at 22:42 UT.

11 **SUNDAY**
Eighth-magnitude comet C/2014 Q2 Lovejoy lies approximately 2.5° southwest of mag. +3.9 Nu (ν) Tauri at 00:00 UT. See page 51.

18 **SUNDAY**
Eighth-magnitude comet C/2014 Q2 Lovejoy lies just over 1° northeast of the mag. +4.3 Delta (δ) Arietis at 00:00 UT. See page 51.

19 **MONDAY**
Neptune, Mars and mag. +4.8 star Sigma (σ) Aquarii form a line in the evening sky; mag. +8.0 Neptune is to the north and mag. +1.2 Mars is in the centre. The trio are an easy target for a small scope.

22 **THURSDAY**
The Moon, now 6%-lit, sits 9° above mag. –3.8 Venus and 6.5° below and right of mag. +1.2 Mars this evening. See page 51.

29 **THURSDAY**
Locate the 75%-lit waxing gibbous Moon as darkness falls and see if you can spot the mag. +0.8 orange supergiant star just below and left of it. This is Aldebaran, the alpha star of Taurus.

31 **SATURDAY**
Fading comet C/2014 Q2 Lovejoy will be approximately 5° to the east of the Triangulum Galaxy, M33, at 00:00 UT. The comet is expected to be around mag. +9.0 at this time. See page 51.

What the team will be observing in January

Pete Lawrence "Jupiter's triple shadow transit on the 24th is something rather special. I tried in vain to catch the last one in daylight under cloudy skies; this one occurs in darkness so fingers crossed it stays clear!"

Chris Bramley "I got a new mount last month and I'm keen to test it out with my setup on the Mare Crisium region of the Moon – particularly that sea's western shore, with its fascinating capes and ridges."

Paul Money "I'll be looking out for Venus and Mercury in the evening twilight for the first few weeks of January. I especially want to catch them at their closest on the 10th."

Need to know

The terms and symbols used in *The Sky Guide*

UNIVERSAL TIME (UT) AND BRITISH SUMMER TIME (BST)

Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT.

RA (RIGHT ASCENSION) AND DEC. (DECLINATION)

These coordinates are the night sky's equivalent of longitude and latitude, describing where an object lies on the celestial 'globe'.

HOW TO TELL WHAT EQUIPMENT YOU'LL NEED

NAKED EYE
Allow 20 minutes for your eyes to become dark-adapted

BINOCULARS
10x50 recommended

PHOTO OPPORTUNITY
Use a CCD, planetary camera or standard DSLR

SMALL/MEDIUM SCOPE
Reflector/SCT under 6 inches, refractor under 4 inches

LARGE SCOPE
Reflector/SCT over 6 inches, refractor over 4 inches

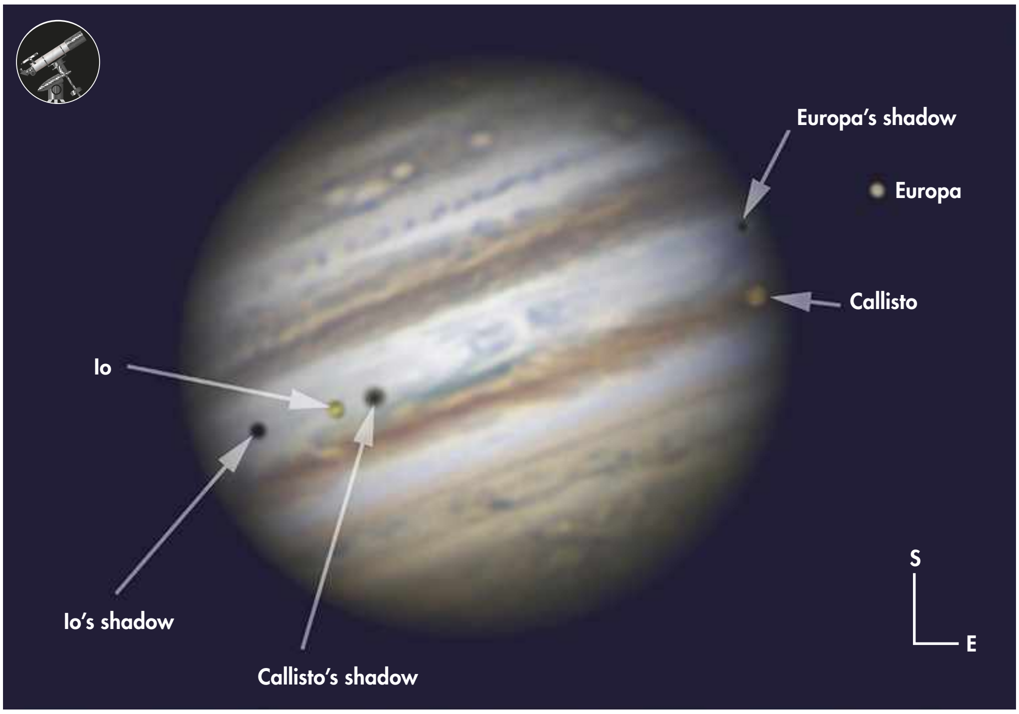
Getting started in astronomy

If you're new to astronomy, you'll find two essential reads on our website. Visit http://bit.ly/10_Lessons for our 10-step guide to getting started and http://bit.ly/First_Tel for advice on choosing your first scope.

DON'T MISS... 3 top sights

A rare triple shadow transit on Jupiter

WHEN: 24 January, 06:28-06:53 UT



The shadows of three of the Galilean moons – Io, Callisto and Europa – can be seen crossing Jupiter's disc between 06:28-06:53 UT on the 24th. The view shown here is correct for mid transit at 06:40 UT

A RARE EVENT occurs during the morning of 24 January; no fewer than three Galilean satellite shadows will be transiting the disc of Jupiter at the same time. We discuss satellite events in more detail on page 67, and there are plenty of these to look out for this month, but the triple transit is something rather special indeed.

This triple is the third of a cluster of relatively recent similar events. The first occurred on 12 October 2013, followed by a daylight triple transit on 3 June 2014. Before these, you'd need to go back to 11 November 1997 for the previous triple – over 17 years ago. Prior to that, on 23-24 January 1985, three moon shadows and three moons appeared to cross Jupiter's disc simultaneously, but Jupiter was too close to the Sun for this event to be seen properly.

When this month's triple shadow transit concludes, you'll have to wait until 20 March 2032 for the next one. This occurs when Jupiter is just 8° above the southwest horizon in broad daylight as seen from the UK, so again the conditions are not ideal.

In contrast, the 24 January event is better positioned and occurs against a reasonably dark sky. Jupiter culminates at 01:30 UT on the morning of 24 January, 53° up and due south as seen from the centre of the UK. The Great Red Spot will be visible at this time, though it rather shyly slips from view just after 02:00 UT and stays hidden for the remainder of the night.

Things start to get interesting at 03:11 UT when the shadow of Callisto can be seen eating into Jupiter's eastern limb. Callisto's shadow is joined at 04:35 UT by the shadow of Io. The three shadow-casting moons can also be seen off planet at this time. Closest to the limb is Io, then Callisto and finally Europa. Io itself starts to cross Jupiter's disc at 04:55 UT.

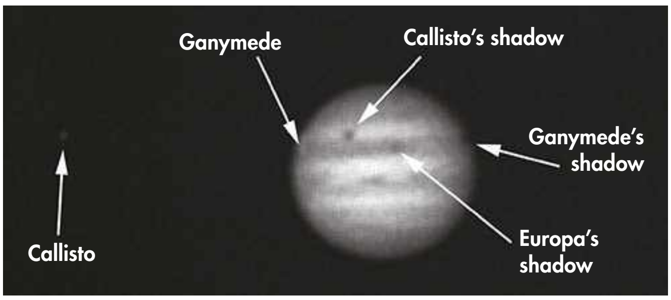
Both transiting moon shadows appear to merge from 05:41-05:58 UT and consequently, during this period, the penumbral part of Callisto's shadow partially eclipses Io.

Callisto begins to transit Jupiter at 06:16 UT just as on-disc Io catches up with Callisto's shadow. The four transiting features are joined by the shadow of Europa at 06:28 UT; all five transits remain on disc until 06:53 UT, when Io's shadow transit comes to an end.

When the triple starts at 06:28 UT, Jupiter's altitude will be 21°, but this decreases to just 18° by the time the event ends at 06:52 UT. This also coincides with the dawn twilight starting to lighten noticeably, but this will not be a problem while observing this particular event.

NEED TO KNOW

An object's brightness is given by its magnitude. The lower the number, the brighter the object: with the naked eye you can see down to mag. +6.0.



The last Jovian triple shadow transit was in daylight on 3 June 2014; this image was obtained through a prevailing cover of thin cloud

PETE LAWRENCE X4

Comet C/2014 Q2 Lovejoy

WHEN: All month, best seen between 9-23 January

THERE'S A DECENT chance of spotting binocular comet C/2014 Q2 Lovejoy this month as it passes up from below Orion, through Taurus and into Andromeda. On the 1st the comet is expected to shine at mag. +8.3, but its low altitude will make it harder to spot than this brightness may suggest.

The comet increases in brightness to mag. +8.1 around the first week of January, then gradually dims to mag. +9.0 at the end of the month. Despite dimming, its increasing altitude will help its visibility.

On 1 January, as Big Ben chimes in the New Year, the comet is in Lepus, the Hare, close to the mid-point between mag. +3.6 Mu (μ) and mag. +3.2 Epsilon (ε) Leporis.

On the morning of 2 January, it passes approximately 2° south of the red variable star R Leporis, also known as Hind's Crimson Star.

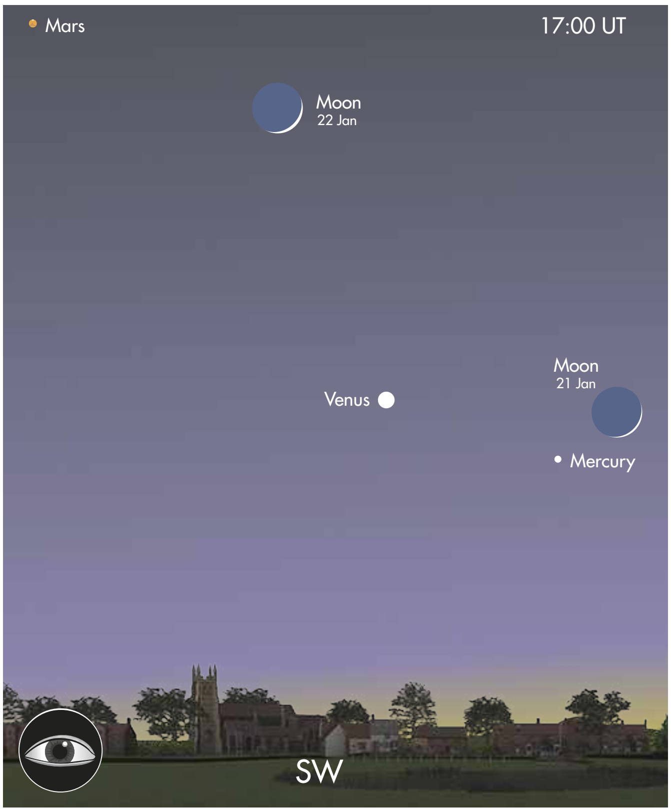
The comet moves from Lepus into Eridanus, and is located roughly midway between mag. +4.0 Omicron (ο) and mag. +2.1 Nu (ν) Eridani at 21:00 UT on the 6th. It enters Taurus on 9 January, after which the bright Moon – which will have been hampering views at the start of the month – will move out of the way, leaving the sky nice and dark for comet hunting.

Lovejoy passes a couple of degrees southwest of mag. +3.9 Nu (ν) Tauri on the evening of 10 January and less than 1° northeast of mag. +4.1 star 5 Tauri on the evening of the 14th.

▲ C/2014 Q2 Lovejoy travels from Lepus through to Andromeda this month

On 17 January, it will be approximately 9° southwest of the Pleiades open cluster, and close to mag. +4.3 Delta (δ) Arietis. It briefly passes through eastern Triangulum towards the end of the month. By the 31st, it just manages to creep into the constellation of Andromeda.

The best time to look for comet C/2014 Q2 Lovejoy will be in the earlier part of the evening, when the Moon's out of the way between 9 and 23 January.



Venus, Mars and Mercury converge on the Moon on the 21st and 22nd

Evening conjunctions

WHEN: Throughout the month as specified

THERE'S A LOT going on low in the southwest just after sunset. Brilliant Venus, shining at mag. –3.8, is joined by Mercury for most of January, the pair having a very close encounter on the 10th. Mag. +1.1 Mars is there too, to the east of Venus. Despite being dimmer, Mars sits against a darker sky background and so should still be easy to spot.

Venus appears close to the Sun at the start of the month, but its intense brilliance will keep it visible. Mag. –0.7 Mercury heads up from below Venus for the first half of January. Both planets are less than 1° apart between 7 and 13 January, and just 39 arcminutes apart on the 10th.

By the 21st, Mercury will be separated from Venus by just over 6° and will have dimmed to mag. +0.6. A beautiful 1%-lit waxing crescent Moon lies just to the right of it on this date. The following evening, the Moon, now 6% lit, can be seen a little above the midway point between Mars and Venus. As Venus moves eastward against the stars, Mars appears to keep pace with it. However, Venus is gaining ground; the pair will be very close at the end of February.

NEED TO KNOW

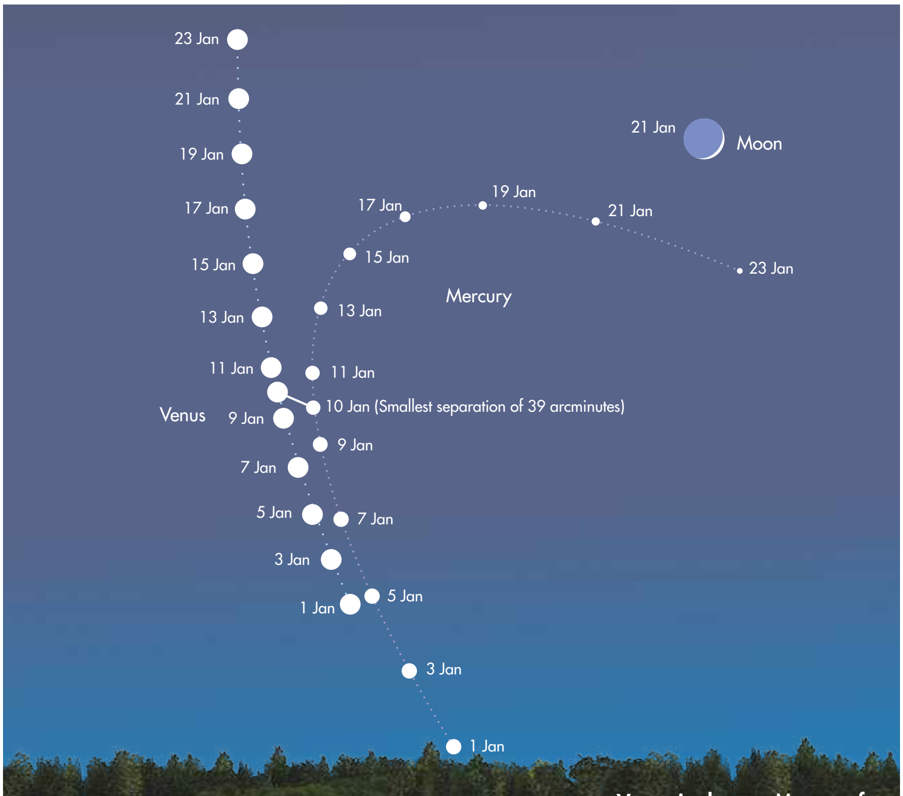
The size of objects in the sky and the distances between them are measured in degrees. The width of your little finger at arm's length spans about 1°.

The planets

PICK OF THE MONTH

MERCURY

BEST TIME IN JANUARY:
10 January, 17:00 UT
ALTITUDE: 5° (low)
LOCATION: Capricornus
DIRECTION: Southwest
RECOMMENDED EQUIPMENT:
3-inch telescope
FEATURES OF INTEREST:
Phase, subtle markings



Venus is close to Mercury for much of January; the pair are closest on the 10th

THE NEW YEAR brings with it a good view of planet Mercury. At the start of the month this tiny world sets about an hour after the Sun and is visible in the southwest, not too far from brilliant Venus. In fact it'll remain close to its dazzling Solar System neighbour for the first half of January, making Venus a useful pointer when trying to locate Mercury.

Mercury remains at around mag. –0.7 up until it has a close encounter with Venus on the 10th. On this evening, Mercury and Venus will be separated by just 39 arcminutes, or about 1.3 times the apparent size of the full Moon. Both planets are less than 1° apart from 7-13 January.

For the first half of the month, Mercury looks small through a telescope – it is less than 7 arcseconds across – and shows a phase greater than 50% lit. Greatest eastern (evening) elongation occurs on 14 January, when Mercury will be 18.9° from the Sun, setting one hour and 45 minutes after sunset.

After greatest elongation the planet starts to fade, becoming harder to spot in the evening twilight. On 20 January, Mercury will shine at mag. +0.4 but if you can get a telescope on it, will be showing an 8-arcsecond disc with a 30%-lit crescent.

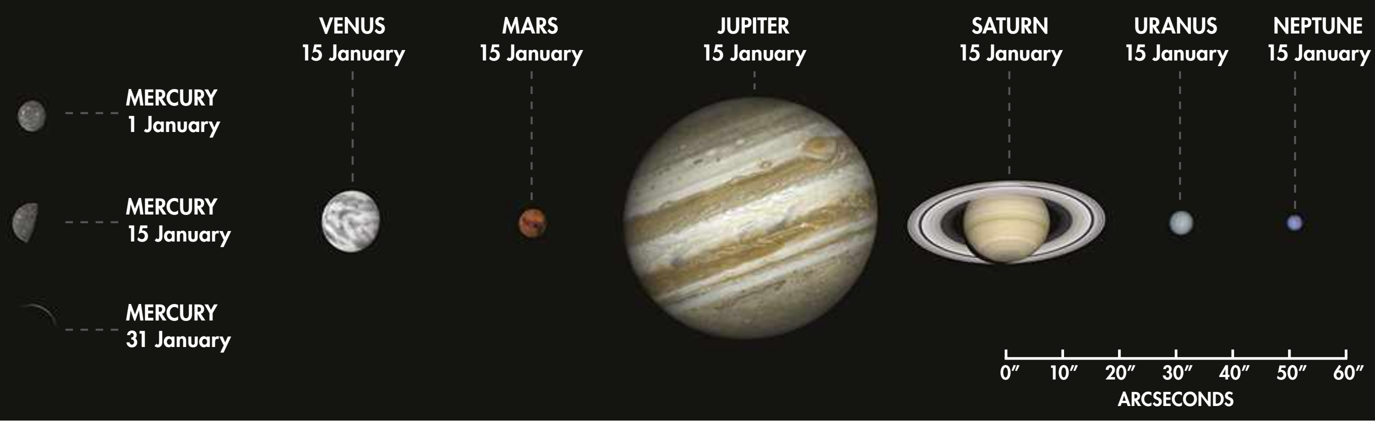
A delicate, 1%-lit waxing crescent Moon lies a little over 2° to the north of the planet on 21 January. As it continues to fade the evening twilight will eventually engulf it. The last view of Mercury is likely to be had around 26 January when the planet will be at mag. +2.8, presenting a 9-arcsecond, 5%-lit crescent when viewed through a telescope. Inferior conjunction then occurs a few days later on 30 January.


A thin crescent Moon will sit north of Mercury on the 21st

PETE LAWRENCE X 3

THE PLANETS IN JANUARY

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



JUPITER

BEST TIME IN JANUARY: 31 January, 01:00 UT
ALTITUDE: 53°
LOCATION: Leo
DIRECTION: South

Jupiter is the best planet on view at present and doesn't disappoint even through a small telescope. At the start of January it appears at mag. –2.4, rising in the east-northeast around 19:30 UT. It remains favourably placed all month.

Use a high magnification to view its atmospheric features. Its belts and zones typically contain lots of subtle detail, and these move fairly quickly from east to west due to the planet's less than 10-hour rotation. A 92%-lit waning gibbous Moon sits 6.3° southwest of Jupiter on the 7th, the bright planet easily standing out even in the Moon's bright glare. The highlight Jovian event will be the triple moon shadow transit on the 24th.

VENUS

BEST TIME IN JANUARY: 31 January, 17:15 UT
ALTITUDE: 13°
LOCATION: Aquarius
DIRECTION: Southwest

Venus is a magnificent evening object and can be seen low in the southwest as the sky is darkening just after sunset. At mag. –3.8, the planet is something of a beacon and will be joined by Mercury for much of the month. Closest apparent approach of both planets occurs on the 10th, when they'll be separated by just 39 arcminutes. A thin waxing crescent Moon joins the scene on the evenings of the 21st and 22nd. Through a scope the planet's disc is a quite small 10 arcseconds across. Its phase is nearly full, because it's on the far side of its orbit relative to Earth. As the month progresses, Venus slowly becomes better placed.

MARS

BEST TIME IN JANUARY: 1 January, 17:30 UT
ALTITUDE: 14°
LOCATION: Capricornus
DIRECTION: Southwest

Mars is an evening object low in the west-southwest after sunset. This mag. +1.1 orange dot isn't well placed at present, but on the 19th it will be 16 arcminutes from mag. +8.0 Neptune. The two planets form a line with mag. +4.6 Sigma (σ) Aquarii on this date.

SATURN

BEST TIME IN JANUARY: 31 January, 06:00 UT
ALTITUDE: 15°
LOCATION: Scorpius
DIRECTION: South-southeast

Mag. +0.6 Saturn is a morning object, but fails to culminate as dawn breaks by month end. On the 16th, a waning crescent Moon sits 2.6° northwest of the planet. The rings are now nicely tilted as seen from Earth, the angle reaching 24.9° by the close of January.

URANUS

BEST TIME IN JANUARY: 1 January, 18:15 UT
ALTITUDE: 41°
LOCATION: Pisces
DIRECTION: South

Uranus culminates as darkness falls at the start of the month, but its position worsens through January. The mag. +5.9 planet is 3° south of mag. +4.4 Delta (δ) Piscium.

NEPTUNE

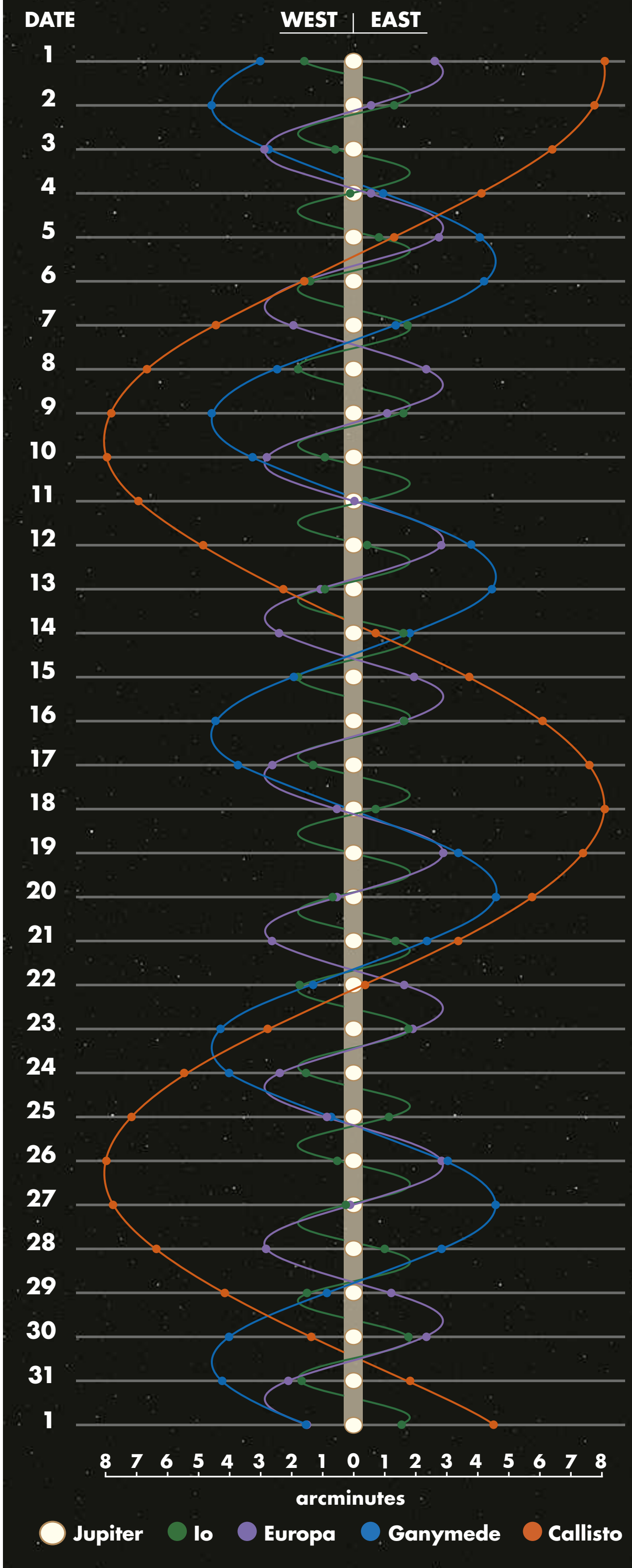
BEST TIME IN JANUARY: 1 January, 18:00 UT
ALTITUDE: 21°
LOCATION: Aquarius
DIRECTION: Southwest

Mag. +8.0 Neptune is past its best for the current viewing period and losing altitude as the sky darkens by the end of the month. Mars lies 17 arcminutes south of the planet on the 19th.

See what the planets look like through your telescope with the **field of view calculator** on our website at:
http://www.skyatnightmagazine.com/astronomy-tools

JUPITER'S MOONS
January

Using a small scope you'll be able to spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date on the left represents midnight.



The Northern Hemisphere

KEY TO STAR CHARTS

- *Arcturus* — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- ASTERISM (Circlet)
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

- COMPASS AND FIELD OF VIEW (N, E, S, W)
- MILKY WAY

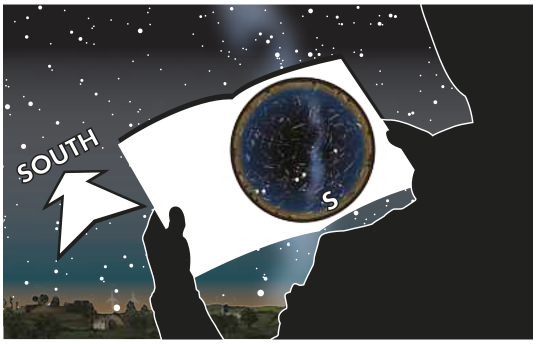
WHEN TO USE THIS CHART

1 JANUARY AT 00:00 UT
15 JANUARY AT 23:00 UT
31 JANUARY AT 22:00 UT

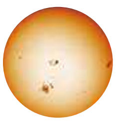
On other dates, stars will be in slightly different places due to Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

HOW TO USE THIS CHART

1. **HOLD THE CHART** so the direction you're facing is at the bottom.
2. **THE LOWER HALF** of the chart shows the sky ahead of you.
3. **THE CENTRE OF THE CHART** is the point directly over your head.



THE SUN IN JANUARY*



DATE	SUNRISE	SUNSET
1 Jan 2015	08:26 UT	16:01 UT
11 Jan 2015	08:22 UT	16:15 UT
21 Jan 2015	08:12 UT	16:31 UT
31 Jan 2015	07:57 UT	16:50 UT

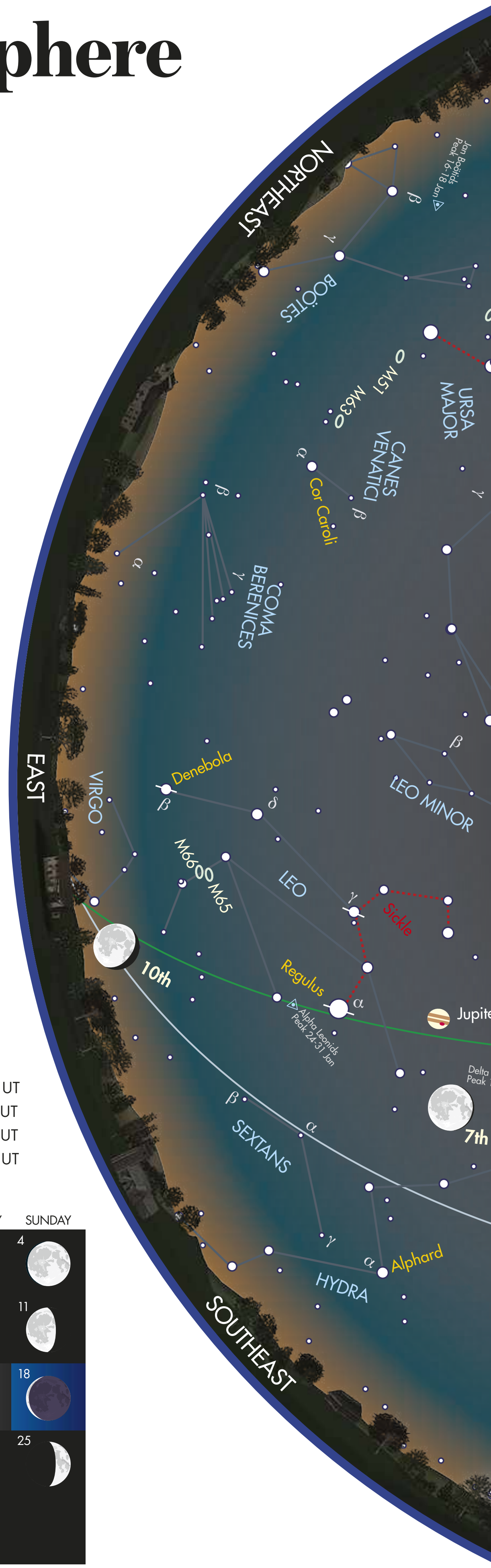
THE MOON IN JANUARY*

MOONRISE TIMES

- 1 Jan 2015, 13:40 UT
- 5 Jan 2015, 17:01 UT
- 9 Jan 2015, 21:13 UT
- 13 Jan 2015, 00:26 UT
- 17 Jan 2015, 04:53 UT
- 21 Jan 2015, 08:15 UT
- 25 Jan 2015, 10:13 UT
- 29 Jan 2015, 12:22 UT

*Times correct for the centre of the UK

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
			1	2	3	4
5 FULL MOON	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20 NEW MOON	21	22	23	24	25
26	27	28	29	30	31	




NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
HERCULES
CYGNUS
Deneb
DRACO
M39
LACERTA
Alderamin
CEPHEUS
Garnet Star
House
M52
Thuban
Kochab
URSA MINOR
Polaris
Alcor
Mizar
M101
M40
Plough
Dubhe
Merak
M82
M81
CASSIOPEIA
Schedar
W
M103
Double Cluster
Scheat
Great Square of Pegasus
PEGASUS
Alpheratz
M110
M31
M32
ANDROMEDA
CAMELOPARDALIS
NGC 2403
Mirphak
M34
M33
TRIANGULUM
PISCES
Algol
PERSEUS
Hamal
ARIES
M74
25th
LYNX
Capella
Kids
AURIGA
M38
M36
M37
Elnath
TAURUS
Zeta Aurigids Peak 31 Dec
M45
Pleiades
CANCER
GEMINI
Castor
Pollux
Rho Geminids Peak 8/9 Jan
M44
M67
M35
M1
1st
28th
Ecliptic
Aldebaran
Hyades
V
4th
31st
Menkar
Mira
CETUS
Quadrantids Peak 3 Jan
January Draconids Peak 13-16 Jan
Cancrids Peak 17 Jan
CANIS MINOR
Procyon
Betelgeuse
Bellatrix
ORION
Celestial Equator
ERIDANUS
Zaurak
Winter Triangle
MONOCEROS
M78
Mirror of Venus
M42
Deep-sky tour, p57
Rigel
M50
M46
M47
Sirius
LEPUS
M79
PYXIS
PUPPIS
M41
CANIS MAJOR

Deep-sky tour

It's familiar and famous, but there are still surprising depths to the Orion Nebula region

☑ Tick the box when you've seen each one

The Orion and Running Man Nebulae: one is a tricky spot, the other is unmissable

1 NGC 1980

The southern end of Orion's Sword is marked by mag. +2.8 quadruple star Iota (ι) Orionis – also known as Na'ir al Saif or 'the Bright One on the Sword'. It is located in NGC 1980, a young open cluster embedded in faint nebulosity. A small telescope shows the cluster's 20 or so stars arranged as a loose, northeast-pointing triangle. NGC 1980 is estimated to be between 1,300 and 1,370 lightyears away and is the older sibling of the Trapezium Cluster, which lies at the heart of the Orion Nebula. Though it formed out of the same material, NGC 1980 is now regarded as a separate entity that lies in front of the main nebula. ☐ **SEEN IT**

2 THE ORION NEBULA

The Orion Nebula, M42, lies 0.5° north of Iota Orionis and is quite frankly hard to miss. A small scope reveals a kidney-shaped region of glowing gas, with fainter swept-back extensions. The bright core is known as 'the Thrust' and has a mottled appearance. The northwest extension is known as 'the Sail' and the sharp-edged southern one confusingly as 'the Sword'. The nebula is bright enough to exhibit colour, especially with larger apertures. M42 is believed to be a blister of hot, ionised gas on the surface of the dark and much larger Orion Molecular Cloud. It is estimated to be 24 lightyears across and contains the equivalent mass of 2,000 Suns. ☐ **SEEN IT**

3 THE TRAPEZIUM CLUSTER

The energy that creates the beauty of M42 comes from the Trapezium Cluster (designated Theta^1 (θ^1) Orionis) that sits at its core. So called because of the pattern made by its four brightest stars, the cluster has formed out of the nebula material itself. Two of the four stars, (A and B) are eclipsing binaries (A is mag. +6.7-7.5, period 65.43 days; B is mag. +8.0-8.5. period 6.47 days). The brightest member is mag. +5.1 C, estimated to be 40 times as massive as the Sun and 210,000 times as luminous. Other fainter cluster stars can also be seen with larger scopes and these have been marked in our inset chart. G, I, H1 and H2 are proplyds – stars surrounded by a disc of material left over after their formation. Planets may form within these discs. ☐ **SEEN IT**

4 M43

Dark material blocks M42's light just to the east of the Trapezium Cluster, forming a shape known as the 'Fish's Mouth'. To the north of this feature is variable star NU Orionis. This star sits at the centre of M43, a comma-shaped nebula separated from M42 by a dark lane of material. Also known as De Mairan's Nebula, M43 is notably fainter than M42 and looks relatively smooth in a 8-inch or smaller instrument. Larger scopes will start to reveal an uneven texture. The tail of the comma lies north of NU Orionis and on the eastern edge it looks like a right-angled piece has been removed from the otherwise round nebula. ☐ **SEEN IT**

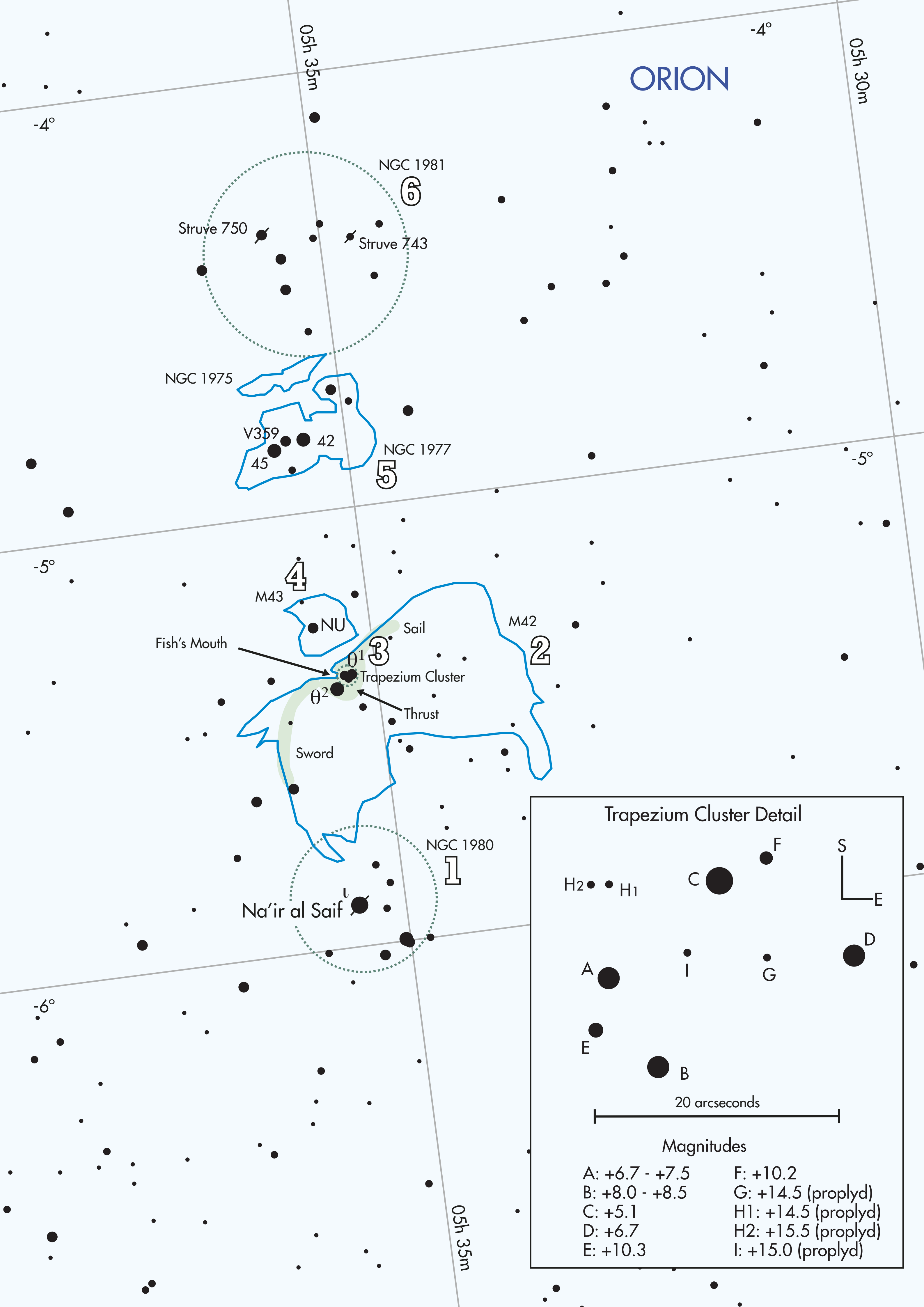
5 THE RUNNING MAN NEBULA

Just 0.5° north of the Trapezium Cluster is another open cluster, designated NGC 1977 and known as the Running Man Nebula. The cluster consists of a dozen or so stars, but the nebula the name suggests isn't immediately obvious. Three prominent cluster stars form a bent line with two brighter ones (42 & 45 Orionis) at the ends and a dim one (V359 Orionis) in the middle. The nebula is brightest in the region around these stars. A 3-inch scope shows little more than a haze, but the nebula takes on a more arc-like appearance through larger instruments, while long exposures show plenty of faint nebulosity. Dark lanes cross the nebula, creating the outline of a running man. ☐ **SEEN IT**

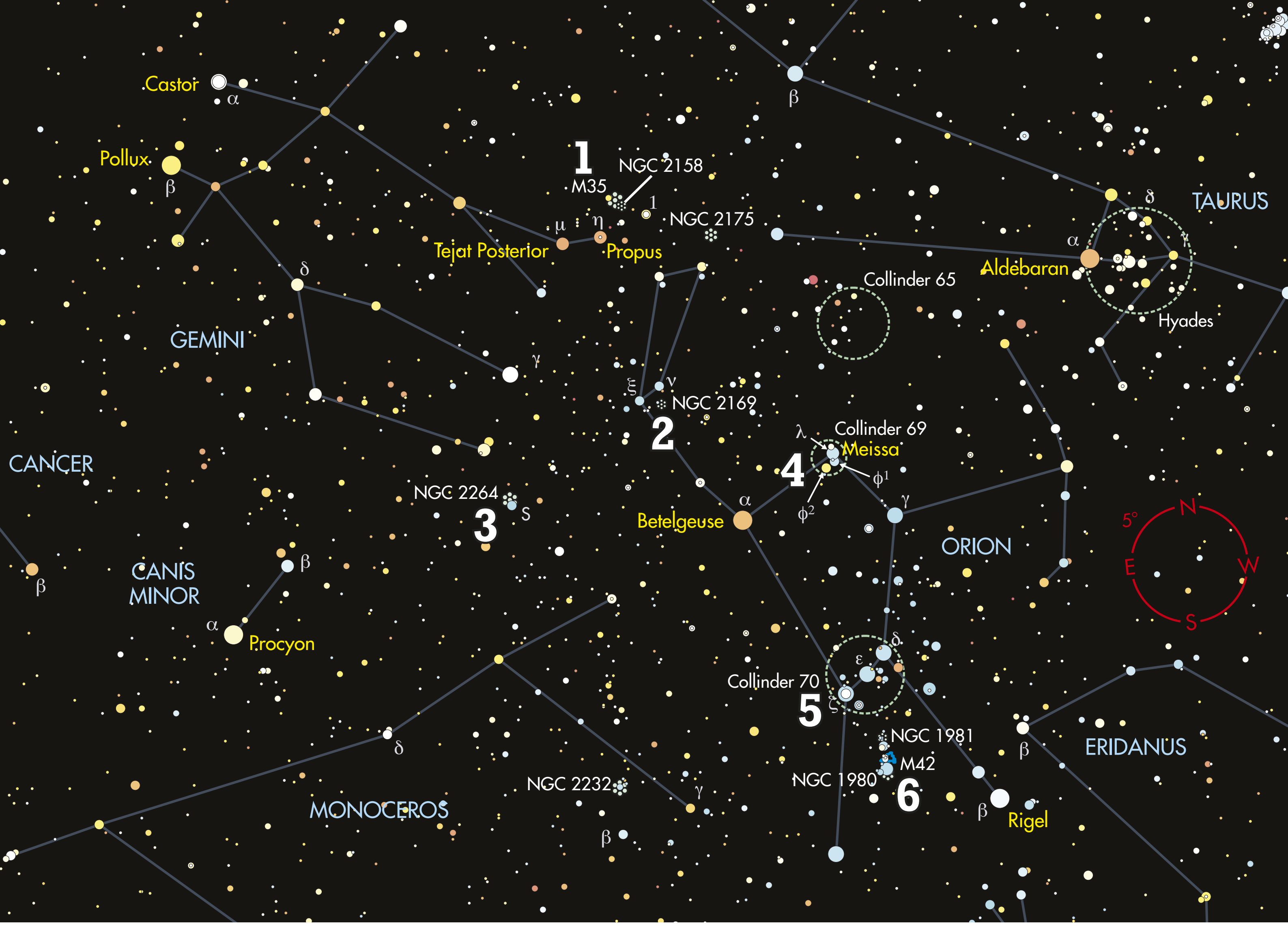
6 NGC 1981

The northern end of Orion's Sword is marked by open cluster NGC 1981. A small scope reveals about 16-18 stars here, scattered loosely to the north of NGC 1977, while a 6-inch scope will show about 50. The cluster contains two lovely double stars known as Struve 750 and Struve 743. Struve 750 splits into two stars of mag. +6.4 and +8.4 separated by 4.2 arcseconds, described as lucid white and pale blue. Struve 743 is a harder target due to a smaller separation. Here you're looking for a mag. +7.7 and +8.2 pair separated by just 1.8 arcseconds. ☐ **SEEN IT**

CHART: PETE LAWRENCE; PHOTO: THINKSTOCK



ORION
05h 35m
05h 30m
-4°
-4°
-5°
-5°
-6°
NGC 1981
6
Struve 750
Struve 743
NGC 1975
V359
42
45
NGC 1977
5
4
M43
NU
Sail
M42
2
Fish's Mouth
3
θ1
Trapezium Cluster
θ2
Thrust
Sword
NGC 1980
1
ι
Na'ir al Saif
05h 35m
Trapezium Cluster Detail
F
S
E
H2
H1
C
D
A
I
G
E
B
20 arcseconds
Magnitudes
A: +6.7 - +7.5
B: +8.0 - +8.5
C: +5.1
D: +6.7
E: +10.3
F: +10.2
G: +14.5 (proplyd)
H1: +14.5 (proplyd)
H2: +15.5 (proplyd)
I: +15.0 (proplyd)



Binocular tour

We kick off the new year with a regal cluster, and the fish of Orion

With
Stephen Tonkin

☑ Tick the box when you've seen each one

1 M35

10x50 If you put mag. +2.9 Tejat Posterior (Mu (μ) Geminorum) and mag. +4.2 star 1 Geminorum in your field of view you should see a large misty patch in the top half of the field. This is the aptly named Queen of Clusters, M35. It shines at mag. +5.1 and is about the same apparent size as the Moon. You should be able to resolve a dozen or so stars in 10×50 binoculars. Using averted vision if necessary, see if you can glimpse the smaller (5-arcminute diameter) NGC 2158, a mag. +8.6 cluster 0.5° to the southwest. ☐ **SEEN IT**

2 NGC 2169

15x70 Halfway between Tejat Posterior and mag. +0.5 Betelgeuse (Alpha (α) Orionis) are a pair of brilliant white mag. +4.4 stars, Nu (ν) and Xi (ξ) Orionis. In the same field of view, on the Betelgeuse side of the pair, is a 7-arcminute diameter rectangular cluster of stars that has an empty centre. This is NGC 2169. If you mount your binoculars and ensure that they are perfectly focused, you should be able to resolve it enough to see that the stars of this rectangle form the number 37, which gives it the nickname the '37 Cluster'. ☐ **SEEN IT**

3 THE CHRISTMAS TREE CLUSTER

10x50 In the north of faint Monoceros lies NGC 2264, the Christmas Tree Cluster; it's just 2° north of the centre of a line joining Betelgeuse and mag. +2.9 Beta (β) Canis Minoris. The cluster surrounds slightly variable star S Monocerotis (mag. +4.6-4.7), which forms the trunk of the inverted Christmas tree, the characteristic narrow wedge of which is easy to discern in binoculars. Note how few faint stars there are in this region of the Milky Way – this is thought to be due to a large amount of interstellar dust in the region. ☐ **SEEN IT**

4 THE MEISSA CLUSTER

10x50 Orion's head looks distinctly fuzzy to the naked eye and, if you look at it through binoculars, you can immediately see why: it is a small cluster of stars, designated Collinder 69 and dominated by the brilliant white mag. +3.5 Meissa (Lambda (λ) Orionis). It's alternative name is Heka, which means 'the white spot'. The other two bright stars in the field of view are the sapphire blue mag. +4.4 Phi¹ (φ¹) and deep yellow mag. +4.1 Phi² (φ²) Orionis, which is probably not part of the cluster. You should be able to resolve about another 10 stars in this sparse object. ☐ **SEEN IT**

5 COLLINDER 70

10x50 The odds are that you have already seen Collinder 70 without knowing it: it is the cluster that includes the belt stars of Orion. On a clear night, you should be able to see at least 70 stars, some forming beautiful curving chains, in this magnificent oval cluster. They are mostly of a blue-white colour, with a few yellow stars here and there. It is an association of stars that has formed about eight million years ago from a giant molecular cloud that includes the Orion Nebula and which contains hundreds of protostars. ☐ **SEEN IT**

6 THE ORION NEBULA

10x50 Although the Orion Nebula is visible to the naked eye as the blurry central 'star' of Orion's sword, this nearest stellar nursery to Earth – superb in binoculars of any size – is very sensitive to sky transparency. For this reason, the best time to observe it is usually when the rain from a cold front has cleaned the sky of dust, when you should easily make out the 'Fish's Mouth' and the 'Wings'. ☐ **SEEN IT**

CHARTS AND PICTURES: PETE LAWRENCE

Moonwatch

The Mare Vaporum

THE MARE VAPORUM is a relatively small elliptical sea measuring 330x200km and is located slightly north of the centre of the Moon's disc as seen from Earth, nestled in the region between the Mare Imbrium, Mare Serenitatis and Mare Tranquillitatis. This makes locating Mare Vaporum relatively easy.

Telescopically, the dark lava covering Vaporum's floor is fairly nondescript to the west as it flows into the foothills of the giant Appenine mountain range. When the Sun is low in the lunar sky, shadows creep along Vaporum's floor and reveal a number of wrinkle ridges, more obvious to the south and west. A small raised patch is present in the middle of the northern region of the sea and there are various lunar domes clustered here.

To the east of this complex is a subtle north-south ridge that passes just west of the small crater Manilus D (5km). A 7x11km volcanic lunar dome sits slightly north and west of Manilus D, again best seen under oblique illumination.

Manilus (40km) is the more substantial crater located close to Vaporum's eastern shore. It's a prominent crater with a sharp rim rising to a height of 2,400m; it also contains a central mountain complex.

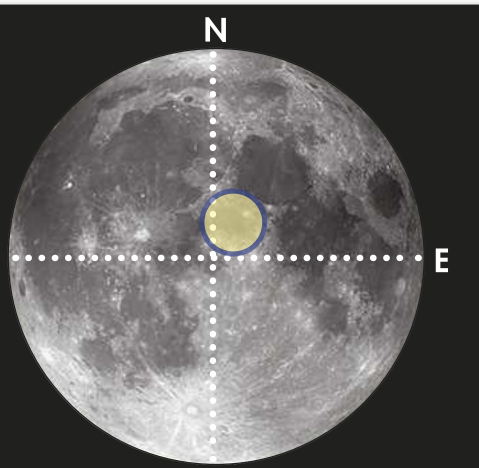
A gap in the southern boundary of Vaporum naturally leads the eye towards the fantastic Rima Hyginus. This appears as a crack that seems to change direction when it passes the 10km crater Hyginus. It's reminiscent of a bird gliding towards you, with the crater representing the bird's body and the cracks its wings. Craterlets appear along the crack sections, indicating that volcanism may have played a part in the feature's formation. The region of mare immediately north or Hyginus is much rougher than the rest of Vaporum. The most prominent feature visible to the west of Hyginus is the slightly triangular crater Ukert (23km).

If you fancy a challenge, there are a couple of unusual features on the northern shores of the mare that are worth looking out for with high magnification. The first lies close to the small crater Yangel (9km). Once you've located the crater look just to the south of it, heading in towards the Mare Vaporum. Here you'll find a roughened terrain. Concentrate and see if you can make out the curious form of Rima Yangel. This appears as a 2km-wide flat track that resembles an east-west road running through the region.

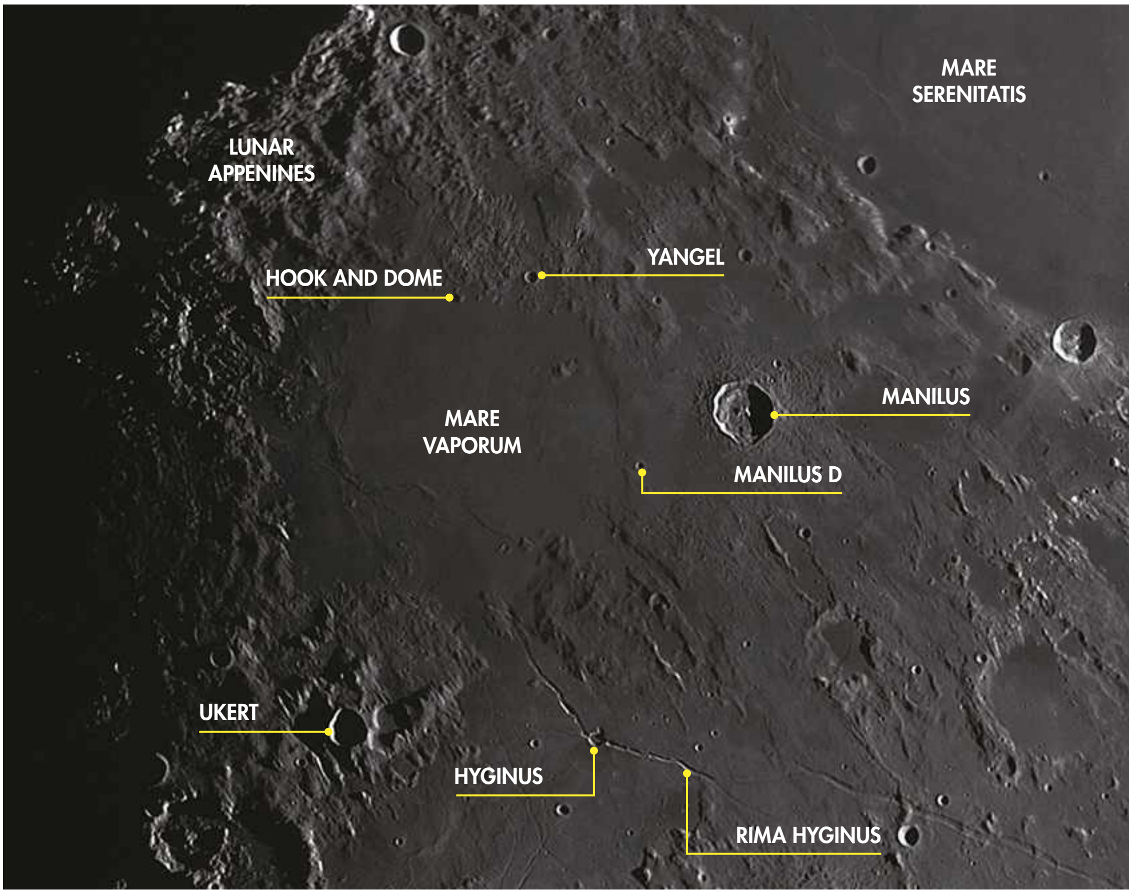
Approximately 45km to the west of Yangel lies another curiosity. Here there's a dark volcanic dome that sits on the southern edge of a small, 5km circular crater rim. The part of the rim to the west is higher and better defined than that to the east. Together these are referred to as the 'hook and dome'.

STATISTICS

TYPE: Lunar sea
SIZE: 330km long and 200km wide
AGE: 3.9-4.2 billion years
LOCATION: Latitude 4.1°E, longitude 13.2°N
BEST TIME TO OBSERVE: First quarter or six days after full Moon (mornings of 11-12 January and evenings of 27-28 January)
MINIMUM EQUIPMENT: Binoculars



"A gap in the southern boundary leads the eye to the fantastic Rima Hyginus"



The Mare Vaporum is easy to find, surrounded by three other lunar seas: Imbrium, Serenitatis and Tranquillitatis

Astrophotography

Imaging the core of the Orion Nebula

RECOMMENDED EQUIPMENT

DSLR with remote shutter release on a long focal length scope, or a long-exposure planetary camera on a medium focal length scope; polar aligned and driven mount

There's rich texture to be seen in M42's core – the trick is not overexposing it in the first place

Orion is high in the sky as seen from the UK so I'm going back to an old friend, the Orion Nebula, or M42. This big and bright object is something that most imagers will dabble with at one time or another, but it's always worth returning to every so often to practice learned skills or experiment with new techniques.

The nebula is large, measuring 85x60 arcminutes, but also contains a number of interesting regions that can be treated as targets in their own right. Just as M42 can be enjoyed using a variety of optical instruments, from binoculars through to large telescopes, so a variety of cameras can be employed to squeeze detail out of it.

M42's size, brightness and complexity makes it a great wide-field target, and one especially suited to a DSLR coupled to a short focal length telescope. Indeed, even a basic camera lens will record it as a brightly coloured patch in the middle of Orion's Sword. On the subject of colour, a standard DSLR does struggle because of its limited hydrogen-alpha wavelength response. M42 is rich in this wavelength, which gives parts of the nebula a distinctive red colour. The infrared-blocking filters fitted to most commercial DSLRs tend to cut out a portion of this light, resulting in a nebula that looks more magenta than red.

Camera choices

The technique of imaging M42 with a DSLR and scope is straightforward. For the best results, use a polar aligned and driven mount. An inexpensive adaptor can be used to connect the camera directly to a scope, so that the scope becomes the camera's lens. Focus as accurately as you can on a bright star, then line up on M42.

If your camera has a live view, refocus on the Trapezium Cluster at the heart of the nebula; its four main stars make a great focus target. Use longer exposures for the outer regions and shorter ones for the bright core; these can be combined using layer-masking techniques.

A monochrome CCD camera and filters opens up different options for capturing the region. A hydrogen-alpha pass filter, for example, will only capture hydrogen-alpha light, resulting in a clean and crisp representation of glowing hydrogen gas in the nebula. This can then be used to enhance other filtered results – for example, adding it as a luminance layer to an RGB image to bring out the detail. This is a great way to pick out the delicate tendrils of gas as they waft away from the bright centre.

M42's kidney-shaped core can be a problem because it's so much brighter than the outlying regions. The core also contains the famous Trapezium Cluster, which if you're not careful can become lost in an overexposed splodge of white.

The bright core is known as the Thrust and is interesting to image in its own right. A longer focal length scope such as a Schmidt-Cassegrain can get you right into the detail, and getting the exposure just right can reveal its amazing texture. Being relatively bright, this is a part of the nebula which can also be imaged with high frame rate planetary cameras that offer longer exposure modes.

KEY TECHNIQUE

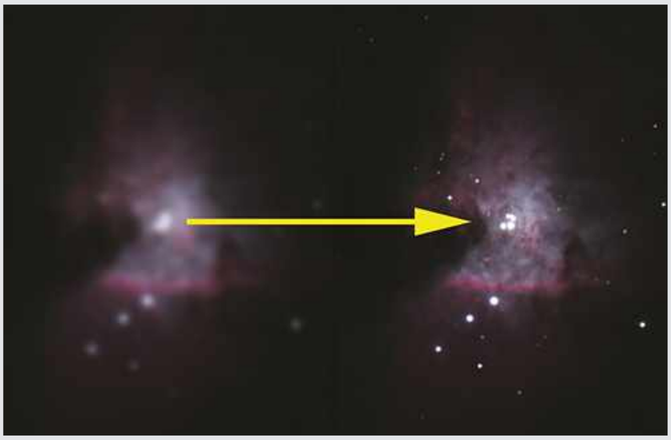
GETTING DETAIL FROM THE CORE

This month we're looking at using a program normally used for planetary image processing to reveal the inner core of M42. We'll look at how using RegiStax to process a set of deep-sky images can produce a result ready for final tweaking in a graphics editor. Being so bright, the core lends itself well to this sort of processing. While a typical image of the nebula may concentrate on capturing the whole thing, a close-up of the core allows us to see its amazing mottled texture, which is often overexposed and lost.

✉ **Send your image to: hotshots@skyatnightmagazine.com**

STEP-BY-STEP GUIDE

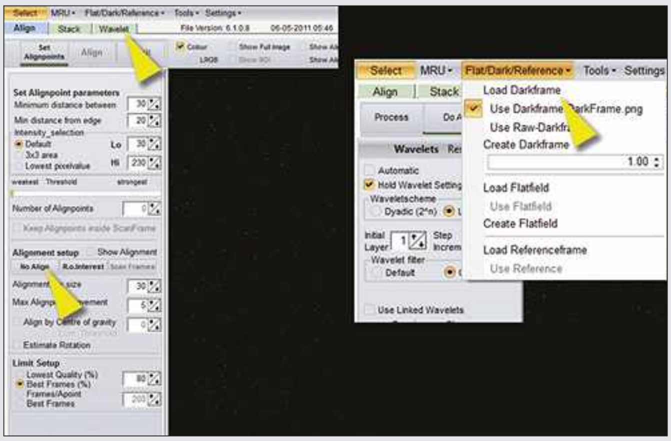
STEP 1 A DSLR attached to a long focal length scope (say, 10 inches and f/10) is ideal for capturing the core of M42. Alternatively a long exposure planetary camera attached to a smaller, mid-range focal length scope (4 inches and f/9) will work well too. The mount needs to be accurately polar aligned and driven or autoguided.



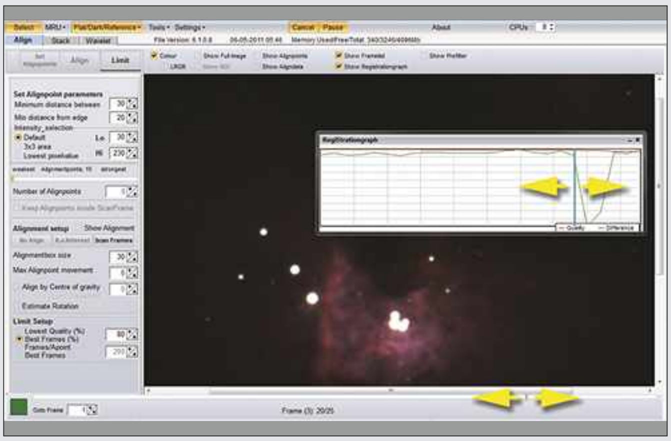
STEP 2 Line the scope up with M42's core. The Trapezium stars are relatively bright and distinctive. Focus as accurately as possible on them: as focus is reached the stars should separate into individual dots, making it easier to identify the precise point of focus. If using a planetary camera, keep the exposure to two seconds or less while focusing.

STEP 3 For a DSLR set the ISO to 800 or 1600 and take a 30-second exposure. Examine the result: if the Trapezium looks burnt out and individual stars are lost, reduce the ISO; if too dark, increase exposure. For a planetary camera, set the gain to around 50 per cent and repeat the DSLR process above, reducing the gain if the end result is too bright.

STEP 4 Once you're happy with the result, repeat the exposures at least 25 times. Cover the telescope and create a repeat set of dark frames. If you took the images in raw format, it will be necessary to convert them to a lossless format such as png before the next step. There are several freeware programs that can do this, such as the Faststone Viewer.



STEP 5 In RegiStax, click 'Select' and choose the dark frames. Click 'No Align' and then in the Wavelet tab 'Reset Wavelets'. Uncheck 'Use Linked Wavelets' and click 'Do All'. Save the result. Click on 'Flat/Dark/Reference', then 'Load Darkframe', selecting the file just saved. Click 'Select' and choose the M42 shots. Click on stars across the image to set the align points.



STEP 6 Click on 'Align'. In the resulting registration graph, drag the slider so that only high quality (say 90 per cent or better) frames are used – the quality is indicated by the red graph line. Click 'Limit', then 'Stack'. When done, click the Wavelet tab, 'Do All' and 'Save'. Load the end result in a graphics editor and apply a gentle unsharp mask and curve adjustment.

RED5

4D VISION SATURN V

1:100 SCALE MODEL

Are you looking for an awesome focal point for your room? Are you crazy about science and all things spacey? Good, because we have found arguably one of the coolest models we have ever seen! Brilliantly detailed, and satisfyingly big, the 4D Vision Saturn V Rocket will be the envy of anyone who sees it.

In homage to this incredible piece of technology, we are proud to introduce the awesome 4D Vision Saturn V model. This 180 piece kit comes pre painted and can be easily assembled. Building the rocket itself is a learning experience and as it is a cutaway model you can see all the bits and bobs that made it work. With the Lunar Module and Command Module included, you get the full space experience at home or in the office.

Measuring a whopping 1108mm when built, this 1:100 scale model is a great gift for space lovers and looks brilliant once complete.

£179.95 at www.RED5.co.uk

NEXTIME MOON CLOCK

WITH GLOW IN THE DARK FACE

As many of us will never get the chance to travel to the moon, we thought we could bring it to you in the form of this awesome glow in the dark clock.

These clocks are made with the latest in glow in the dark technology, so as night falls, your NeXtime Moon Clock will change from grey to a soothing blue tone. This soft blue hue adds a relaxing feel to your room as you drift off to sleep. Each hand has a blue glowing tip so even if you wake up in the middle of the night, one look at this moon and you will know the time. When the real moon has disappeared again and the sun is out, your blue moon will gently fade back to its original self.

£24.95 at www.RED5.co.uk

3D IN ZERO G

Sean Blair looks at how 3D printing could change the face of space exploration forever

By the time you read this, it has already happened. With a click of a mouse in a Silicon Valley office, a data file was uploaded to the International Space Station (ISS), allowing the very first off-world manufacturing to take place. The 3D printer that reached the ISS in September has completed its historic first item, made from the same plastic as Lego bricks. Down on the ground, 3D printing – properly known as additive manufacturing – has been termed ‘the third industrial revolution’. Now this technology has made it into orbit, could space exploration be revolutionised too?

Today, space is at the end of a long and costly supply chain: everything in orbit gets manufactured on the ground, goes through extensive testing, then gets propelled out of Earth’s gravity well at upwards of 8km/s. It’s a supply chain that will stretch further still as future missions venture beyond Earth orbit. But NASA, together with start-up company Made in Space, aims to change that by making parts right where they are needed – in space, that is – thanks to 3D printing.

Launching a revolution

On the ground, 3D printing has ushered in a quiet revolution. From collectibles to solar cells, dental implants to rocket combustion chambers, almost anything that can be designed can be 3D printed. Software-based designs are built up, layer by layer, from an ever-widening choice of materials – hence the alternative term additive manufacturing.

Made In Space began by testing off-the-shelf 3D printers in weightless conditions aboard parabolic flights. But there was a problem, says Mike Snyder, the firm’s lead engineer: “They didn’t work! In the absence of gravity parts would go out of alignment and the print quality would degrade. We realised we would have to design our own.”

Their work was supported through a NASA contract. “NASA experts helped us ▸

▲ Off-the-shelf 3D printers didn’t work in microgravity, so a new one for space had to be designed

THINKSTOCK X 2, MADE IN SPACE/INC

▸ through the safety aspects of designing for the ISS – the printer has to be contained so that it doesn't affect the crew, for example by releasing fumes or particulates."

The resulting box-shaped machine reached space on 23 September 2014. It prints from a spool of plastic filament that is melted into place in layers as thin as 0.25mm and a minimum vertical thickness of 1mm. Parts up to 5cm wide, 10cm long and 5cm tall can be produced.

"The printer operates from inside the ISS's Microgravity Science Glovebox, ensuring safe containment," says Snyder. "Results from early testing will guide development of our follow-on printer, the Additive Manufacturing Facility, which will be more capable and employ a greater range of plastics. It will also have its own containment, so can be housed within its own rack instead of the glovebox."

Candidate designs for 3D-printed space tools are being crowdsourced through a US-only online competition. "Right now everything has to be shaped around the need to stand up to Earth gravity, then the 2G to 7G launch loads," says Snyder. "Printing in weightlessness means items will end up looking quite different."

This second printer is due to reach orbit next year, with its customers expected to include microgravity experimenters as well as NASA itself.

"When you set up an experiment on Earth, you can repeat it, improving things that don't work," adds Snyder. "On the ISS it might take years to get redesigned parts up. But with 3D printing adaptations can be made rapidly.

▲ The ISS's first 3D-printed part was a piece of the printer's casing; highlighting that the technology will allow astronauts to produce 'spares' as needed; left, the printer itself

"Tools and replacement parts can also be produced," he adds. "Right now the ISS carries a collection of spares that might never be used. Sometimes tools have to be jury-rigged – for instance, spacewalkers had to modify a toothbrush to help unfasten one stuck bolt." Snyder estimates 30 per cent of all parts on the ISS could be replaced by 3D-printed constructs.

Next year will also see Europe's first 3D printer on the ISS: Italy's POP3D will produce a single plastic part that remains inside its printer, which will then be flown down to compare with a ground-produced equivalent. Made In Space's next step will be a recycler able to process waste plastic aboard the ISS into printable material.

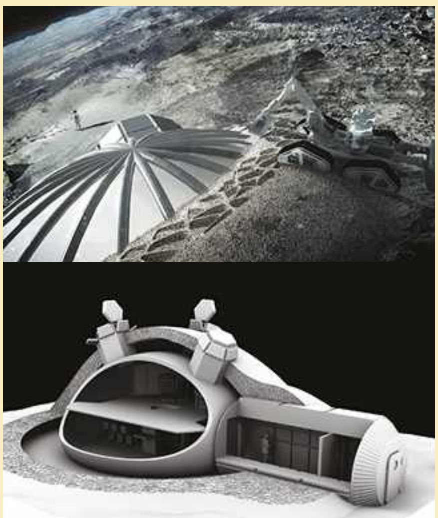
From plastic to metal

But plastic parts are limited in function. That's why a NASA team has developed the Electron Beam Freeform Fabrication (EBF3) for wire-based metal 3D printing.

"We have to attain temperatures around an order of magnitude higher than the few hundreds of degrees needed to melt plastic," says Karen Taminger of NASA's Langley Research Center. "But the resulting metal parts can handle higher loads and a much greater temperature range, along with electrical

3D PRINTING ON **OTHER WORLDS**

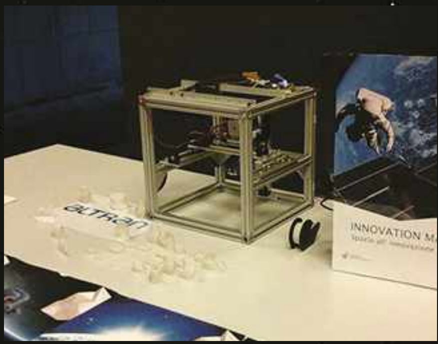
Spacefaring 3D printers rely on raw materials from Earth, but research is being done into how astronauts could make use of materials found on alien worlds, allowing expeditions to 'live off the land'. In 2013, ESA collaborated with an industrial team including renowned architects Foster + Partners to research printing a Moon base using ground-up lunar rock. "One of our key findings was that the printing method we chose – applying a binding liquid – still worked in a vacuum, within which liquids boil away," says ESA engineer Laurent Pambaguian. "But millimetre-scale droplets we used are preserved by capillary forces in the soil." As a proof-of-concept, a 1.5-tonne building block was produced using simulated regolith. "As a next step, we're looking into fusing regolith using focused sunlight." 'Glassifying' Moon rock in this fashion might also help cut down on troublesome lunar dust.



▲ ESA's 3D-printed lunar base concept would be made entirely from lunar dust

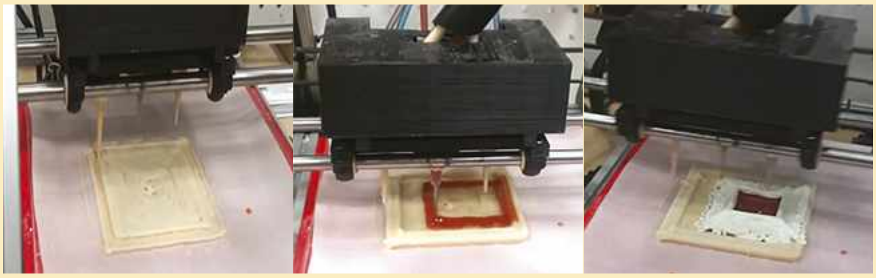
▲ 3D printers have no trouble creating complex shapes like those in this sculpture

MADE IN SPACE/INC, NASA, ESA/FOSTER + PARTNERS X 2, MONOLITE, ALTRAN ITALIA, NASA/SEAN SMITH, SYSTEMS AND MATERIALS RESEARCH COPRORATION/YOUTUBE X 3, THINKTSOCK X 2



▲ ESA's plastic printer POP3D will be sent to the ISS for product testing next year

▲ The EBF3 system can deliver temperatures capable of melting metal wire for 3D printing



▲ A pizza printer sounds like the stuff dreams are made of; the pizza itself, rather less so

A REAL **REPLICATOR?**

"Tea, Earl Grey. Hot." Captain Picard and the rest of the USS Enterprise crew could rely on their trusty food replicators to keep them in home comforts, no matter how far they ventured into the final frontier. What might real-life astronauts have to look forward to?

3D-printed food is already a reality, mainly yielding high-end desserts for now. Last year a NASA-funded pizza printer was unveiled at the SXSW Eco festival in Texas. Modified from the open source RepRap 3D printer, the prototype printed layers of dough followed by tomato sauce, then a 'protein layer' – which turned out to mean cream cheese. The long-term aim is to avoid monotonous diets during long-duration space expeditions by combining freeze-dried ingredients in novel ways.

'Bioprinters' – 3D printers capable of generating living tissue – might end up being more indispensable. 3Dynamic Systems, a company spun off from Swansea University, is working on printing artificial bone and other biologically compatible materials. On average, astronauts lose one per cent of their bone mass per month in weightlessness. Bioprinters would offer a means of bone regeneration in advance of reentering a planetary gravity field.

and thermal conductivity and corrosion resistance."

The EBF3 has been extensively tested on parabolic flights and now the team is aiming for an ISS berth, either inside or outside the station. "The electron beam process operates in a vacuum – and there's a lot of vacuum in space," says Taminger. "Outside would give us more room, although the printer would have to be partially shrouded to prevent contamination of any exterior surfaces, such as solar panels."

Either way, the aim is to prove that items to be used in space can be built there and to extend this capability further afield. "The ISS has a finite lifetime and we want to take advantage of it while it's there," Taminger adds. "It's not really built for repair and replacement – if a single board or component breaks down the entire unit is swapped over. But the further we go, to the Moon, Mars or beyond, that becomes impractical. We want astronauts on manned missions to be able to dismantle systems, do repairs and make things."

Just how far might such an approach go? One 2012 study by NASA engineers proposes that self-replicating machines – in other words, 3D printers that can print 3D printers – could establish an exponentially-growing industrial base.

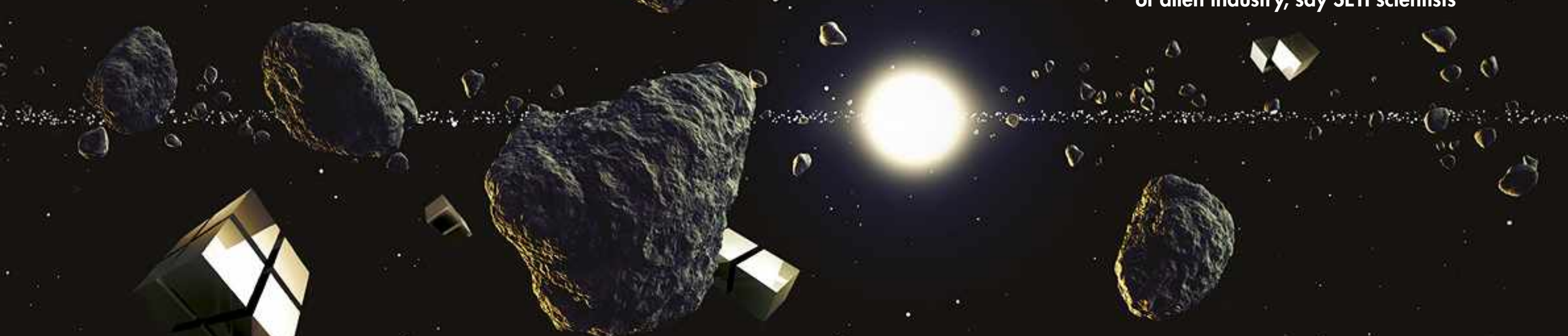
Initially key electronic parts would be sourced from Earth, but with each new generation their reproductive autonomy would grow. Place 41 tonnes of 3D printers and worker robots on the Moon and within 20 years the result would be 40,000 tonnes including 100,000 robots, efforts having expanded out to the mineral-rich asteroid belt. Then, says the report: "Within another few decades, with no further investment, it can have millions of times the industrial capacity of the United States."

SETI astronomers have previously suggested hunting out evidence of vast-scale industry by alien civilisations. It's an awe-inspiring prospect, if also slightly alarming. For our descendants' sake, no matter how autonomous such self-replicating 3D printers become, they should surely always be manufactured with an off switch. Ⓢ

ABOUT THE WRITER

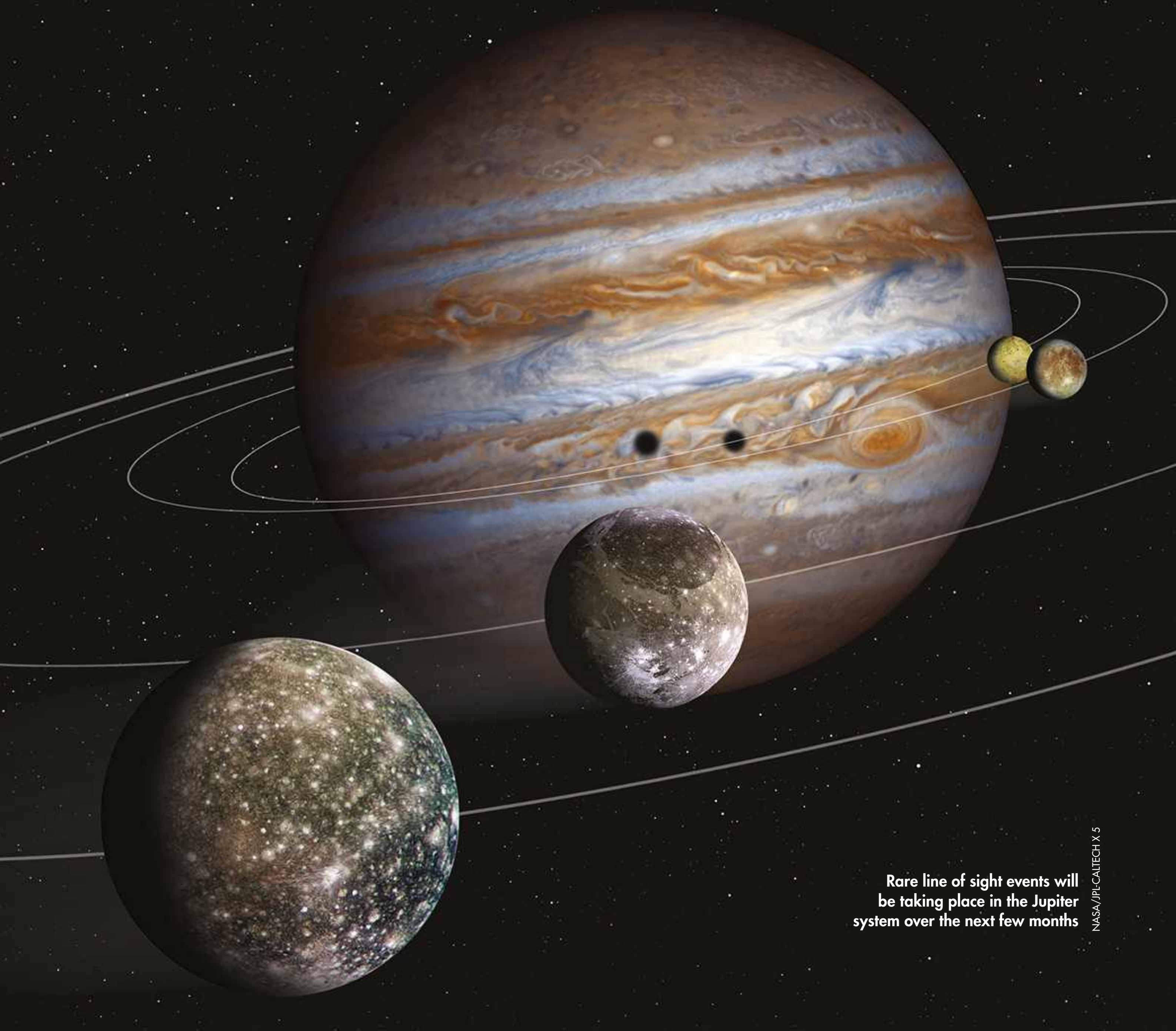
Sean Blair is a science and technology journalist. A former Guinness World Records researcher, he now edits ESA's space engineering website.

Chemical and thermal irregularities in asteroid fields could be evidence of alien industry, say SETI scientists



JUPITER'S dynamic moons

Pete Lawrence explains why now is a perfect time to witness the balletic dance of the Galilean satellites



Rare line of sight events will be taking place in the Jupiter system over the next few months

NASA/JPL-CALTECH X 5

▲ Jupiter's allure is not solely in its moons; its disc is covered in exciting features

Jupiter is a spectacular planet to view through a telescope of any size. This year it reaches opposition on 6 February and it's around this date that it appears at its best. The planet is a telescopic favourite because it is both bright and has a disc that shows plenty of fine detail. In addition, its four largest moons – Io, Europa, Ganymede and Callisto, in order of distance – are mesmerising to watch as they endlessly orbit around Jupiter's globe. These are collectively known as the Galilean moons, in honour of their discovery by Galileo Galilei over 400 years ago.

Each Galilean moon is a sizeable object in its own right, and from Earth they can appear to interact with Jupiter in a number of ways. All four have orbits that are more or less in line with Jupiter's equatorial plane. Europa has the largest orbital inclination of 0.47º, while Io has the smallest at just 0.05º. The three innermost moons also have a 1:2:4 ratio orbital resonance: Europa's orbital period is twice that of Io's 42.5 hours, and Ganymede's twice that of Europa's.

Jupiter's equatorial plane and consequently all the orbital planes of the Galilean satellites appear edge-on from Earth roughly every six years, when Jupiter experiences an equinox. At such times, the equatorial plane of Jupiter lines up with the Sun and, because of our great distance from the planet, our view is pretty edge-on too. Jupiter was actually edge-on to Earth at the start of November 2014 and will be edge-on again for us during mid-April.

Jupiter's axial tilt is quite small at just 3.1º; for comparison, Earth's is 23.5º. Apart from reducing the intensity of Jupiter's seasonal variations, the slightness of this lean also means that even when we see the planet at maximum tilt, the orbits of the Galilean moons appear as very thin ellipses. Note that when Jupiter is at maximum tilt relative to the Sun, the planet is at solstice.

Earthward encounters

With such a small tilt angle, the three inner moons appear to pass in front of, or transit, Jupiter's disc when they're on the Earthward side of their orbit.

> "Each moon is sizeable in its own right and can interact with Jupiter in a number of ways"

Callisto, the outermost moon, can appear to pass above or below the planet when Jupiter is close to solstice, but will transit around 20 months either side of equinox. A transiting moon passes across Jupiter east-west and can be tricky to see visually against the disc.

Moon pairings as viewed through a small scope

Moon pairings as viewed through a large scope

Each Galilean moon casts a shadow in space. When a moon passes between Jupiter and the Sun, the shadow can fall on the planet's disc below, producing a dark spot known as a shadow transit. The one exception again is Callisto: close to Jovian solstice its shadow misses the planet altogether.

Opposition timing affects how a moon and its shadow transit. Before opposition, a shadow will precede its moon across Jupiter's disc. The gap between moon and shadow decreases as opposition approaches; after opposition, the moons precede their shadows. At opposition moons and shadows pass across the disc together, typically offset slightly north or south of one another.

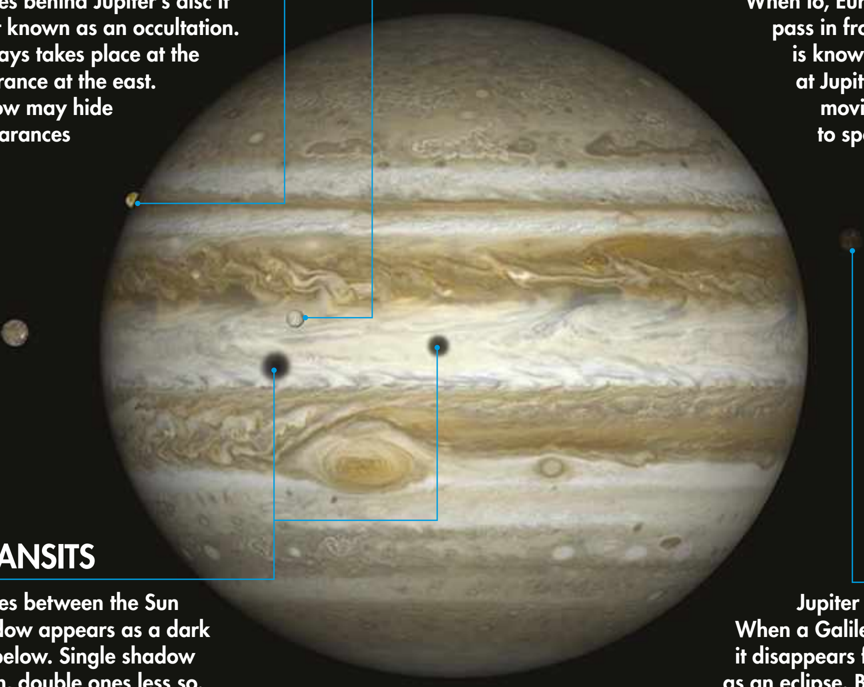
The great shadow

These events happen when the moons are closest to us, but a different set of interactions can be seen when they are on the far side of their orbits. Here, the massive shadow cast by Jupiter comes into play and any moon wandering into this will undergo an eclipse and disappear from view. A moon travelling behind Jupiter's disc will also undergo an occultation.

The sequence of events changes depending on where Jupiter is in relation to the Sun and the distance between a moon and Jupiter. Before ▸

MOON-PLANET **INTERACTIONS**

The interplay between the Galilean moons and their planet take several forms



OCCULTATIONS

When a moon passes behind Jupiter's disc it undergoes an event known as an occultation. Disappearance always takes place at the west limb, reappearance at the east. Jupiter's own shadow may hide occultation disappearances before opposition and reappearances after opposition.

MOON TRANSITS

When Io, Europa, Ganymede and Callisto pass in front of Jupiter's disc, the event is known as a transit. A transit starts at Jupiter's east limb, with the moon moving east-west. It can be tricky to spot a transiting moon visually.

SHADOW TRANSITS

When a moon passes between the Sun and Jupiter, its shadow appears as a dark spot on the planet below. Single shadow transits are common, double ones less so. The triple shadow transit on 24 January (see page 50) is really rather rare.

ECLIPSES

Jupiter casts a big shadow in space. When a Galilean moon enters this shadow it disappears from view in an event known as an eclipse. Before opposition the shadow points west of Jupiter; after opposition it extends off to the east.

▸ opposition, Jupiter's shadow points west of the planet. Consequently, as a moon approaches from the west, it will first be eclipsed by Jupiter's shadow before passing behind the planet and reappearing from occultation at the east limb, fully illuminated.

After opposition the situation is reversed: a moon is first occulted by the planet's west limb, then reappears from occultation eclipsed by Jupiter's shadow on the east, suddenly popping into view some way off the edge of the planet as its eclipse ends. This situation is more complex for Ganymede and Callisto: in the run up to opposition these more distant moons may disappear into eclipse but reappear again before undergoing a full occultation behind Jupiter. After opposition they can be first occulted by Jupiter, to temporarily reappear fully illuminated before undergoing a full eclipse.

For a period of approximately nine months centred on Jupiter's equinox, the tilt of the planet is such that the moons may appear to interact with one another in what are known as mutual events. Here one moon may occult another either partially, totally or annularly, when it'll appear to pass fully inside the disc of the more distant moon. The moon shadows may also interact, producing partial or total eclipses. An annular eclipse occurs if one moon's shadow passes inside the disc of another moon but doesn't hide it completely.

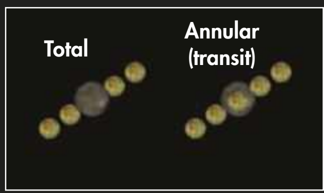
Jupiter's next equinox occurs on 5 February 2015, virtually coincident with opposition. Consequently, now is an ideal time to look out for these fascinating interactions. And just to add extra excitement, on 24 January there will be a triple shadow transit visible between 06:28 and 06:53 UT. Turn to page 50 for the full run down of this rare spectacle.

PETE LAWRENCE X 3, NASA/JPL-CALTECH X 5

MOON-MOON **INTERACTIONS**

Mutual events between the moons of Jupiter fall under one of three types

PARTIAL OCCULTATIONS
A partial occultation occurs when one moon appears to clip the disc of another. These are by far the most common mutual events. Watch one of these interactions through a small telescope and the pair may look like a single moon for a short period.



TOTAL OCCULTATIONS
If a closer moon lines up with a more distant one and covers it completely, it is a total occultation. If the occulting moon is small enough to fit inside the disc of the more distant moon, this is known as an annular occultation.

ECLIPSES
If a moon's shadow cone passes across the disc of another, it produces an eclipse. An eclipse can be partial, total or annular. If the eclipsed moon passes through the weaker outer part of a shadow cone, this is a penumbral eclipse.

ABOUT THE WRITER
Expert imager Pete Lawrence is a regular on the *The Sky at Night* and *Stargazing LIVE*. The author of several books, he also compiles our monthly *Sky Guide*.

10 GALILEAN EVENTS TO WATCH IN 2015

2/3 JANUARY 22:39-03:09 UT Double transit and shadow transit of Io and Europa	**19 JANUARY 02:30-02:36 UT** Ganymede totally occults Europa	**24 JANUARY 06:28-06:53 UT** Triple shadow transit and double moon transit	**3 FEBRUARY 19:25-21:47 UT** Io in transit next to its shadow	**23/24 FEBRUARY** Ganymede transit **19:36-23:03 UT**, shadow transit **21:07-00:45 UT**
27 FEBRUARY 02:17-02:23 UT Io annularly occults Ganymede	**11 MARCH 20:30-20:36 UT** Europa's shadow partially eclipses Io	**20/21 MARCH** Jupiter occults Ganymede **19:22-23:02 UT,** then eclipses it **23:07-02:47 UT**	**8 APRIL 22:54-23:00 UT** Europa annularly occults Callisto	**18 APRIL 01:28-01:37 UT** Callisto annularly occults Ganymede

VISUAL OBSERVING GUIDE

PART 1: THE PLANETS

The first of **Paul Abel**'s three-part guide to visual observing looks at how to get the best views of the planets

There was a time before webcams and CCDs when photographic film had a resolution lower than that of the human eye. During this era, the only reliable tools an astronomer could rely upon was his own vision and a pencil, but even with these limited resources some startling discoveries were made. The astronomers of this era seem to be like great explorers venturing out into a vast and complex cosmos, their drawings and observations rather like postcards from alien frontiers.

Today, the sensitivity and size of imaging equipment has improved immeasurably. Yet even in the 21st Century, there are still areas of amateur astronomy where visual observers can make valuable contributions. Visual observers need many specialist techniques to obtain reliable results that can go into the scientific record and this three-part guide will introduce these observing skills with the aim of making you a better astronomer. We start this month with the most rewarding planets for study: Venus, Mars, Jupiter and Saturn.

VISUAL OBSERVING GUIDE

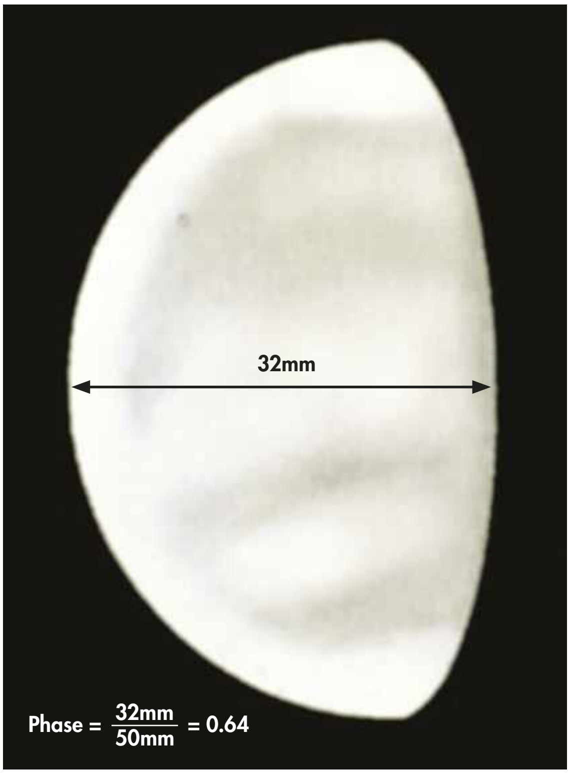
COMING SOON

PART 2: VARIABLE STARS

PART 3: SUPERNOVA PATROLS

ISTOCK

VENUS



▲ **Determining the phase of Venus from your drawing is easy. Simply measure the widest horizontal distance from the limb to the terminator. Here it's 32mm, and so for a 50mm sketching circle the phase is 32/50, which is 64 per cent**

▲ **The Schröter effect is easily seen through a blue filter (middle) in these three views drawn on the same night**

PAUL ABEL X 5, NASA/JPL-CALETCH X 3

VENUS CAN BE a challenging object for visual observers, yet in the 1960s it was such astronomers who helped to establish that the planet's clouds have a three-day rotation period. With Venus, a visual observer's main objectives are to obtain disc drawings that correctly show the phase and to record elusive cloud markings.

A cursory telescopic view of Venus will reveal a bright white disc with a phase. The bright cusp caps covering the poles may be glimpsed, but that will probably be the only detail. Don't be put off, though: with time and patience subtle cloud markings come into view. The first thing to do is to find the correct magnification: one that gives a reasonable disc size and is suitable for the seeing conditions. I find 130-160x to be about right. Venus is also best observed in bright skies, as this reduces the glare from the disc.

As with all planets, don't expect to see all the fine details at once – you will need to engage with your visual system (one of the most remarkable adaptive optics kits on Earth). Ask yourself what you can see on the disc and slowly your eyes will respond. Spend about 15 minutes looking at the planet's disc before you start drawing.

To sketch Venus you'll need a circle 50mm in diameter. Draw in the phase and then, with a 2B pencil, gently shade in the subtle cloud markings. Eyepiece filters are a great help as they allow you to see into different depths of the atmosphere. Red and blue filters help to enhance cloud markings, while a yellow filter will bring out the polar collars.

The Schröter effect

Look at Venus when it's predicted to be at half phase and you'll notice that the phase is actually slightly less than half. This is the Schröter effect, where Venus's observed phase is always less than the theoretical one, and it is particularly prominent in a blue filter.

The phenomenon was first recorded by Johann Schröter in the 1790s and is due to light being scattered in the thick Venusian atmosphere. You can record it for yourself: on your drawing, simply measure the distance (in mm) with a ruler from the limb to the terminator and divide this distance by 50 to get the observed phase of Venus. Do this for all of your drawings and you can plot the decreasing phase against time on a graph and show how the effect changes over the course of an elongation.

KEEPING A **LOG BOOK**

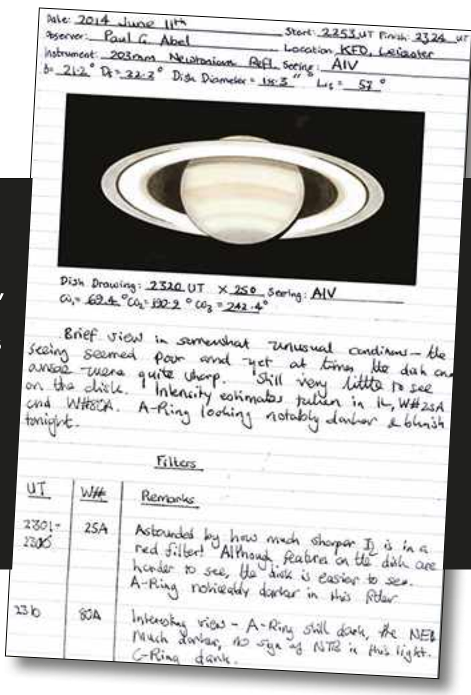
Keeping a log book is an essential skill for any visual observer. It will keep your observations in a logical structure and you'll be able to look back and see how your drawing skills have developed. Your log book should be a sturdy bound notebook, and every observation should include the following information:

THE DATE OF OBSERVATION

THE TIME, always in UT

THE TELESCOPE AND MAGNIFICATION, along with the details of any filters used

THE SEEING CONDITIONS, recorded using the Antoniadi scale, which runs in Roman numerals from I to V; I is perfect seeing and V is a very poor unfocused image.

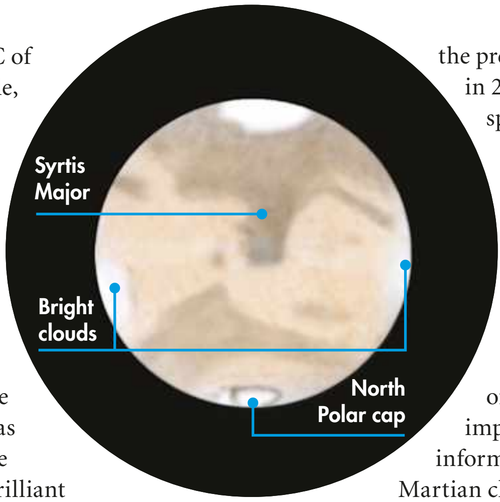


► **A page from the author's Saturn log book shows observation details, a drawing and some filter remarks**

MARS

THE OCHRE DISC of Mars is full of subtle, slowly changing features. Mars is a world of vast volcanoes, continent-sized canyons and majestic deserts. It's not uncommon for fogs to collect in the basins such as Hellas and Argyre, and the volcanoes attract brilliant clouds at their summits. Martian meteorology changes over the course of a few hours, and it can all be recorded and studied visually.

The well-defined Martian seasons produce different phenomena. During the previous apparition in 2013-14, it was springtime in the northern hemisphere, and the brilliant north polar cap shrank dramatically as it sublimated away. Recording the retreat and advance of the polar caps is important as it reveals information about the Martian climate.



▲ Use high magnifications to reveal dark albedo features like the Syrtis Major

The dust-storm season occurs during spring and summer in the southern hemisphere. Telescopically, these storms resemble small orange clouds, and they can engulf the entire planet. It may take many months for the dust to clear and afterwards there may be changes to the dark albedo features. You can track the progress of large dust storms, recording their size and changes to local surroundings. A green filter helps enhance them.

Mars tolerates high magnification well because red light is less affected by Earth's turbulent atmosphere. At powers of 300x, dark albedo features like the Syrtis Major will show a multitude of subtle structure.

Drawing Mars requires some patience. You can't spend any longer than 15 minutes doing so as Mars's rotation will have moved the features away from where you've placed them in the drawing. Sketch the phase first if it is present, then the polar caps. Spend seven minutes putting down the obvious features and use the remaining time to put in any bright clouds you can see. A blue Wratten No 80A filter helps to enhance white clouds. Aim to make two to three drawings over a night to show how the clouds change.

JUPITER

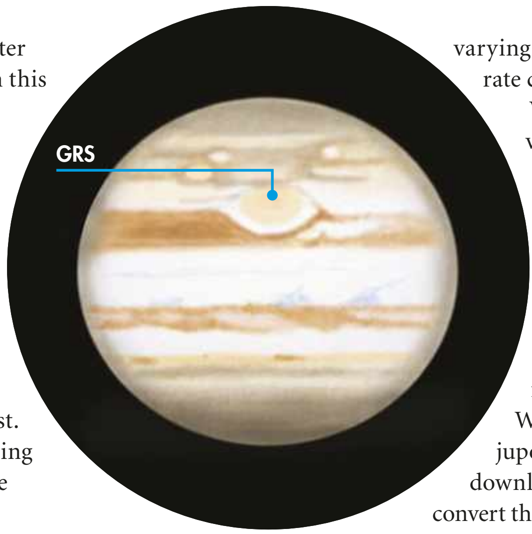
THE RESTLESS CLOUDS of Jupiter have generated plenty of work for visual observers for hundreds of years. Through a telescope, this gas giant is differentiated into darker belts and brighter zones. Powerful jet streams carry large storms along, presenting us with an ever-changing cloudscape.

Jupiter has a large disc and magnifications of 160x or more are sufficient to reveal a lot of fine detail. A red filter helps to enhance bluer features like festoons along the equator. Conversely a blue filter helps to enhance redder objects like the belts and the Great Red Spot. A yellow filter gives good all-round contrast.

It takes practice to record Jupiter correctly, but doing so will really hone your observational skills. A Jupiter drawing requires the correct blank: this planet is appreciably flattened due to its rapid rotation, so the standard blank is 64mm wide but only 60mm high.

Like Mars, Jupiter rotates quickly; in this case you have 10 minutes to make your sketch. First draw the main belts and large storms, recording the ones near the preceding edge first as these will vanish soonest. Spend the remaining time adding in the finer details.

Jupiter's most famous and persistent storm is the Great Red Spot, a vast hurricane situated in Jupiter's South Tropical Zone. Visible to a 5-inch scope, the Great Red Spot drifts in longitude at varying speeds; this drift rate can be measured.



▲ The Great Red Spot moves in longitude but is held at a fixed latitude of 22°S

When the storm is visible, watch as it moves towards the central meridian. When you think its centre is on the meridian, record the time. Use freeware software WinJUPOS (www.jupos.org/gh/download.htm) to convert the time into longitude and repeat this whenever you observe the Great Red Spot. You can plot the resulting longitudes against time and look at how quickly the spot is moving in Jupiter's atmosphere. ▸

SATURN

▲ One of the author's Saturn sketches; the white storms that occur in the equatorial region are best seen with a blue Wratten No 80A filter

IT IS OFTEN said that majestic Saturn is a 'quieter' Jupiter. The belts and zones of Saturn's atmosphere are less well defined, but the storms that this planet can produce are even more ferocious.

Watching and charting storm activity is one of the main tasks for visual observers of Saturn. Storms are seasonal, occurring every 30 years, and usually take the form of a large white oval on Saturn's equator. The next outbreak is due near 2020.

Recently Saturn has produced other storms: quite unexpectedly in late 2010 a large storm erupted in the planet's northern hemisphere, lasting into 2011. This powerful storm churned up the North Tropical Zone, reminding us of the need for a constant vigil if we're to catch the next outbreak.

To really view Saturn, you'll need to use a power of 160x times or more; 250x is a good all-round magnification. Drawing Saturn requires five accurately placed ellipses – so don't try to do it free-hand, use a carefully produced blank.

Saturn is also a quick spinner, so spend about eight minutes drawing in the main features on the disc and the rings, and use the final four minutes to finish the fine details such as the fainter belts and shadows. Filters work well for Saturn: yellow enhances the contrast between belts and zones, while light blue helps to emphasise redder features. Also watch out for a bi-coloured aspect of Saturn's rings: occasionally Saturn's outermost ring, the A-Ring, appears brighter in a blue filter than in a red one. Although rare, this phenomenon has been reported by visual observers and is worth keeping an eye out for. Ⓢ

PAUL ABEL, NASA/JPL-CALETCH, PAUL WHITFIELD

ABOUT THE WRITER

Dr Paul Abel is an astronomer based at the University of Leicester. You can listen to him on our Virtual Planetarium each month.

TOOLS OF THE TRADE

EYEPIECES
A selection of medium- and high-power eyepieces, giving a range of magnifications to suit your seeing conditions. A useful range is 160-190x for low power, 200-250x for medium power and 300x-plus for high power.

FILTERS
These help to enhance different features on planetary discs. Red, blue and yellow filters are invaluable.

PENCILS
Some planetary features are more subtle than others, so you'll need range of pencils from HB to 6B, to capture as many as possible.

RED LIGHT
White light destroys night vision, so always use a red light to draw.

WINJUPOS
This essential free software (www.jupos.org/gh/download.htm) displays the features present on Jupiter or Saturn's disc at any date and time, and gives you the planetary longitudes for both gas giants so you can record the location of details. It is especially helpful as these planets have three systems of longitude due to their different bands of rotation.

THE NORTHERN LIGHTS

With holiday companies releasing details of their latest aurora tours, now's the time to start thinking about booking your trip to see the Northern Lights. There's nothing quite like standing under a starry night sky and watching as this truly magical celestial show dances overhead. There are many ways you can travel in style too. You can sail in luxury with cruise companies voyaging up and down the coast of Arctic Norway, head to the glacial glory of Iceland, or even be a tad more adventurous and join the huskies sledging across the frozen expanses of Lapland. Wherever you decide to go remember one thing... never take your eyes off the skies, you never know when that spectacular display might appear.

THE NORTHERN LIGHTS

BALTIC TRAVEL COMPANY

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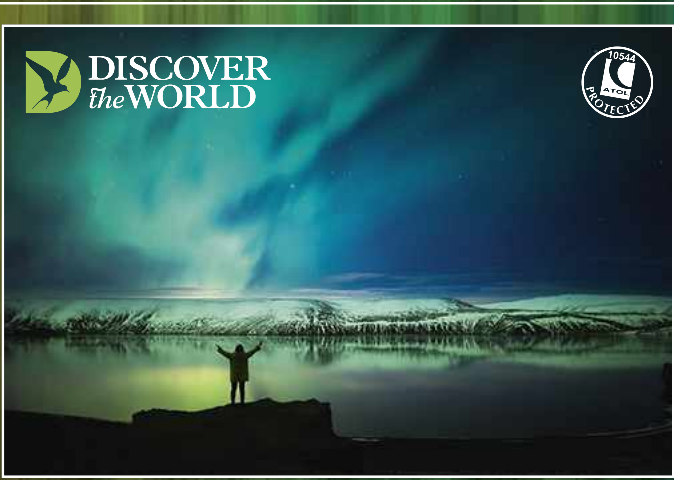

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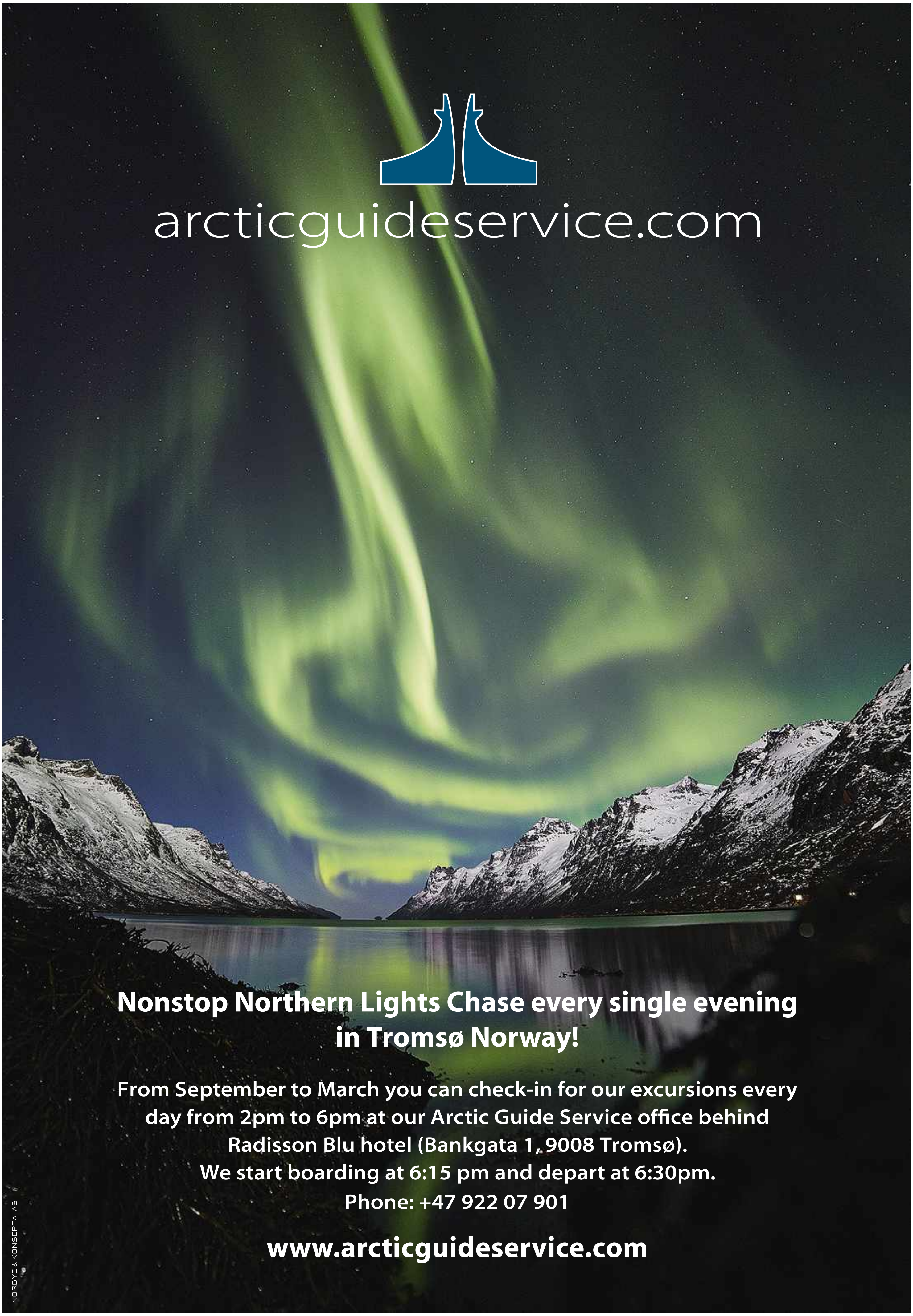
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The Guide

Philae's historic landing

With **Stuart Clark**

Stuart Clark was in Darmstadt at the moment the plucky lander touched down

▲ **Rosetta flight director Andrea Accomazzo (centre) looks on anxiously shortly after receipt of Philae's signal from the surface of the comet**

It was the early hours of the morning on the day of Philae's landing attempt when suddenly it looked as if the whole thing might be called off. Two critical go/no-go decisions had to be taken. The first, for the Rosetta orbiter, was given on time but the second, for the Philae lander, was delayed. Something was wrong. The landing was in jeopardy.

Anxious officials at ESA's European Space Operations Centre (ESOC) were in close communication with the Philae Lander Control Centre in Cologne. They in turn were making phone calls to the industrial partners who had built the lander.

Eventually, an hour later than expected, the lander was pronounced ready. But what had caused the delay? At 6am, I made my way to ESOC to begin the day's reporting and soon discovered that the cold gas thruster designed to hold Philae to the icy comet while the harpoons anchored it to the surface was not working. Overnight, signals from the lander had shown that there was no pressure in the gas supply lines to the thruster. Philae faced the real danger of bouncing off the comet back into space.

"We came close to cancelling the attempt," Paulo Ferri, ESA's head of mission operations, admitted to a small group of journalists who had also struggled in early to get the news. Yet after intense discussion, everyone decided that there was no reason to believe that a delay was likely to restore the thruster. There was nothing to be done but go for it.

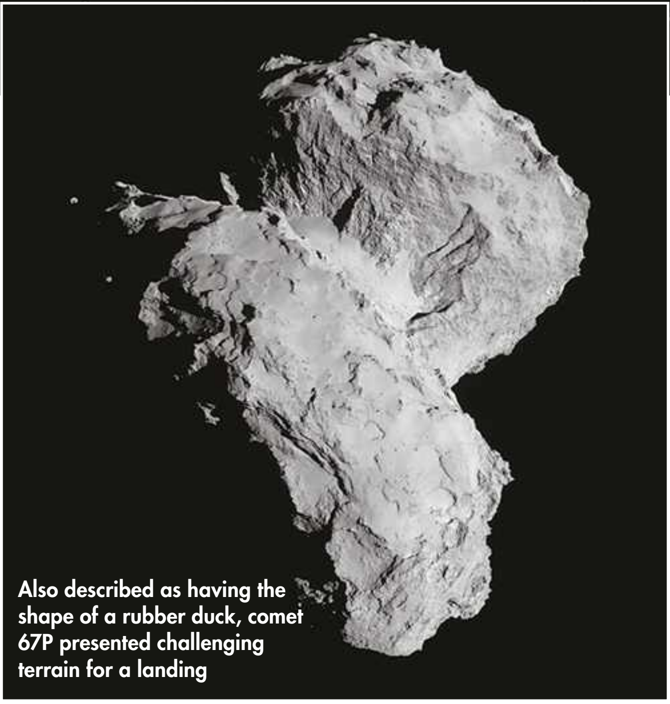
And so began around 10 hours of nervous waiting. The tension was made bearable because there were images and events scheduled throughout the day. Each one of these was like a mile marker, assuring us that everything was going to plan 510 million km away.

The distance was so great, out beyond the orbit of Mars, that the transmissions took more than 28 minutes to reach Earth – but one by one the mission milestones were passed. First, Rosetta took a sharp turn in towards the comet. With the landing site directly in view it released Philae and boosted itself away.

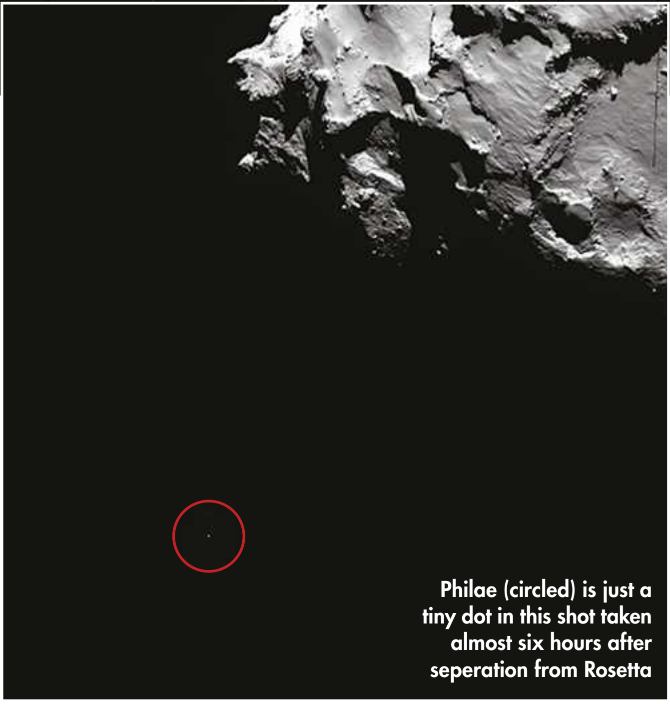
The descent

The first images came mid-afternoon. The room gasped as we saw the picture of Rosetta, its giant panels outstretched like a bird of prey as Philae dropped away underneath. Then there was the picture of Philae itself, landing legs and radar antennas deployed, captured in exquisite detail by the OSIRIS camera on Rosetta.

ESA/J. MAI X 2, ESA/ROSETTA/MPS FOR OSIRIS TEAM MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA X 2, ESA/ROSETTA/PHILAE/CIVA

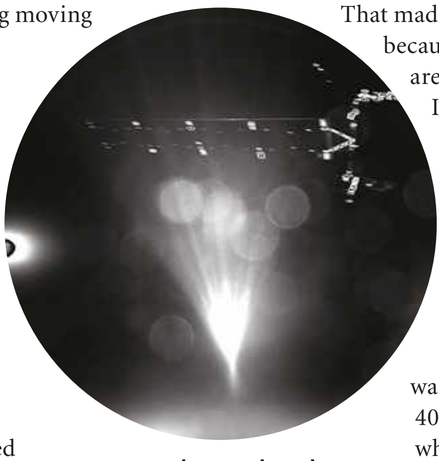


Also described as having the shape of a rubber duck, comet 67P presented challenging terrain for a landing



Philae (circled) is just a tiny dot in this shot taken almost six hours after seperation from Rosetta

There was something moving about that image. The fragile-looking lander was on its way. No one could help it now. And all knew that this might be the last we ever saw of it. Although everything was proceeding as planned, without the thruster system the mission was in clear jeopardy. People wanted to talk about it, people wanted to not talk about it. The thought of the landing failing after 10 years in space and so much success so far was almost too difficult to contemplate. Some words of cautious encouragement came in the afternoon from Fred Jansen, ESA Rosetta mission manager.



▲ Rosetta's solar panel can be seen in this parting shot taken by Philae

"In principle, the ice screws should be sufficient to hold us to the surface," he said. These were attached to each of the landing legs and would literally screw themselves into the surface of the comet due to the force of the landing. This would take place at about 1.5m/s, the equivalent impact of walking headlong into a brick wall. It seemed reassuring but then Jansen added, "If we land on a surface we expect." And the anxiety returned.

Nothing about this comet had been expected. 67P/Churyumov-Gerasimenko was about 4km from end to end but it was not a round 'potato' shape: it looked more like two smaller potatoes shoved together. That made the landing risky because there were not large areas of smooth terrain. Instead the comet was a place of cliffs, depressions and boulder-strewn surfaces. An unlucky landing was every bit as possible as a lucky one.

We had been warned that there was a 40-minute window in which the landing might take place. We settled to watch the live feed of the main control room. All eyes were on Andrea Accomazzo, the Rosetta flight director. Within a minute or two of the window opening, Accomazzo strained towards the computer screen and then leapt to his feet with his arms in the air.

Around me the place erupted. The celebrations began, Philae had touched down – or so it seemed. Then there were anxious faces and confusion and a promised press briefing that was delayed twice. Four hours later we learnt that not only had the thruster failed, so had the harpoons. The ice screws hadn't gripped and Philae had bounced from its original position and had taken more than two more hours to finally come to rest.

It was unknown where Philae was exactly, but it was on the comet, it was communicating with Rosetta. The landing had been achieved. History had been made. Now the science could begin. Ⓢ

Stuart Clark is a science journalist and author of Is There Life on Mars?

Members of the ESA team celebrate after making history with the landing

How to
Build a Dobsonian mount PART 2

With **Steve Richards**

Assemble the mount so it's capable of supporting a telescope

▲ Nearly there: rocker box is assembled, all that's left is to add the base and bearing wheels

In our December issue, we showed you how to cut out all the wooden parts to make a Dobsonian mount. This month, we'll walk you through assembly and finishing the mount ready for use. We'll be referring to our online resources throughout (highlighted in **bold**), so we recommend that you print these out before you begin. Download them from **http://bit.ly/DobMountPt2**.

Start by marking the centre of the rocker box base, then draw a line from one side to the other through this central point. Do the same for your base board.

Take the base board and – using the line you just drew as the 'horizontal' to rest against – use a protractor and ruler to mark off the various points indicated on **Diagram 1**. Drill the holes at the sizes specified on **Diagram 1**, and then a 12mm hole in the centre of the rocker box base, plus a 10mm hole in the centre of a vinyl LP you can bear to live without!

We'll assume that you have gathered all of the fixings, bearings and other parts listed in our **Components** list. Lightly coat the outside of one of the T nuts with epoxy resin and pull it into the top of the base board using a 10mm bolt and washers until it is firmly seated. Drill out the thread of the second T nut using a 10mm drill bit, and install it in the top of the rocker box base in the same manner – use a 10mm bolt, washers and nut.

Take one of the rocker box side panels and mark the centre point on its bottom inside edge; repeat for the other side panel.

Place the two side panels on top of the rocker box base so that the points you just marked match up with the line you drew across the base. Now position the front of the rocker box so that it touches the two sides. Mark its outside edge on the top of the rocker base. Now mark the height of the front piece on the edges of the two side panels; trim these 'horns' so the side panels sit flush against the front panel.

Next, refer to **Diagram 2** and drill out the nine 4.5mm holes in the rocker base as shown; countersink the holes on the reverse. Fix the rocker base, front and side panels together using PVA glue and 15 No 8 1.5-inch screws (nine in the base, three in each side; these also need 4.5mm drilled holes).

Once the glue is dry, draw a pencil line perpendicular to the existing line (which you drew in Part 1) through the centre of each altitude wheel. Centre the dovetail bar of your telescope on this line both vertically and horizontally, then mark and drill the two holes for attaching the tube rings.

Sand all the components and round the corners of the two bases. Apply two

ALL PICTURES: STEVE RICHARDS

TOOLS AND MATERIALS

FIXINGS AND ANCILLARY COMPONENTS
A complete list of all the fixings required to complete the assembly can be found in the components list included with our online resources.

TOOLS
A standard crosshead screwdriver is needed for much of the assembly; Allen keys and spanners are required for some of the retaining bolts.

PAINT OR VARNISH
To give the mount protection from night-time moisture to prolong its life. Make sure the product you use is intended for outdoor use.

TAPE MEASURE, PROTRACTOR AND PENCIL
For accurately marking out the positions of the various components.

ADHESIVES
Both PVA wood glue and epoxy resin are needed.

▲ Using both PVA wood glue and screws to secure the rocker base gives a sturdy end result

coats of external quality undercoat and topcoat paint to all surfaces, rubbing down between coats. Then reduce the height of the screw base and centre tube sections of the adjustable feet to 25mm and attach them to the underside of the baseboard with epoxy resin and No 6 ¾-inch screws.

Bear with it

To make the azimuth bearings, cut the PTFE sheet into three 25mm square pads (unless you are using 'Slide Glides'); secure these in the 1.5mm pilot holes in the rocker box base (see **Diagram 1**) using No 6 ¾-inch screws.

For the altitude bearings, cut four rectangular pieces of PTFE 25mm long by the width of the rocker box sides, then drill and countersink them. Attach them to the top of the rocker box sides spaced as close as possible to 70° apart.

Assemble the rocker box on top of the baseboard, sandwiching the LP – which will act as a ridged bearing surface – as shown in **Diagram 3**. Make sure you leave a 0.5mm gap under the bolt head before tightening the locknut underneath the baseboard.

Cut the edging strip to the correct width with scissors and attach it with impact adhesive to the perimeter of the altitude wheels, securing the ends with No 6 ¾-inch screws and cup washers. Bolt the two circular retainers (the wooden discs you kept over from Part 1) to the centre top of the rocker box sides and apply felt to the inside surface.

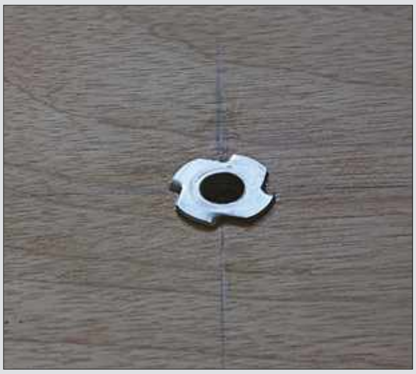
To finish, attach the altitude wheels to the tube rings, sandwiching the dovetail bars, using oversize washers on the outside. Gently lower the altitude wheels into the bearing 'cups' to complete the assembly. As a final option, you can use the swing of the telescope to determine the position for the attachment of a bracing bar.

Steve Richards is a keen astro imager and an astronomy equipment expert

DOWNLOAD THE PROJECT FILES

Visit this link for a complete components list and drilling diagrams: http://bit.ly/DobMountPt2

STEP-BY-STEP GUIDE



STEP 1

Mark the centre of the rocker box base and drill a 12mm hole. Mark and drill the holes in the baseboard in accordance with **Diagram 1**. Drill the threads out of one T nut to form a smooth bearing and insert both T nuts.

STEP 2

Place the rocker box sides and front on the rocker box base and mark their positions carefully. Drill and countersink 4.5mm holes through the rocker box base for attaching the sides and front. Glue and screw the rocker box together using 1.5-inch wood screws.

STEP 3

When the glue has dried, sand all the surfaces including the altitude wheels and the retainer discs. Round off all four corners of the rocker box base and base board with a small radius. Apply two coats of external quality undercoat followed by two topcoats.

STEP 4

Cut down the height of the adjustable feet and install them on the underside of the base board. Attach the three azimuth bearing pads to the baseboard at 120° positions. Attach the altitude bearing pads to the top of the sides, followed by the side retainers and felt.

STEP 5

Place the vinyl LP centrally on top of the azimuth bearing pads then place the rocker box centrally over the base board. Insert a 10mm bolt through rocker box's smooth T nut, vinyl LP and into the T nut on the base board; tighten it with a nyloc nut underneath.

STEP 6

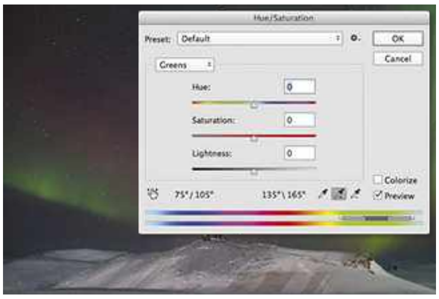
Attach edging strips to the altitude bearing wheels and then attach the tube rings to the telescope. Attach the altitude bearing wheels to the tube rings with oversize washers, sandwiching the dovetail bars. Finally, lower your scope gently onto the rocker box's 'cups'.

Image processing

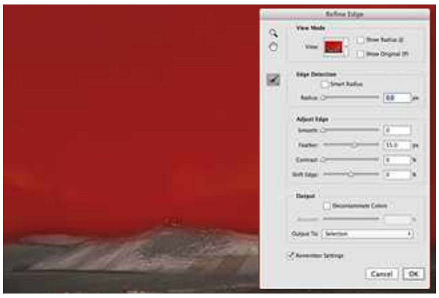
Balanced auroral landscapes

With **James Woodend**

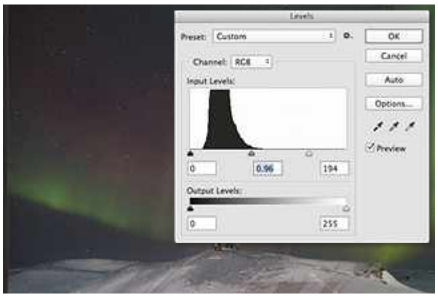
▲ **James's final processed image shows delicate harmony between landscape and aurora**



▲ **Step 7: Use the Hue/Saturation sliders to give your aurora a realistic colour**



▲ **Step 4: Correct underexposure on any foreground objects separately from the sky**



▲ **Step 6: Darken the sky using Levels or Curves, but remember too dark looks unnatural**

One of the challenges of processing aurora images is matching what the human eye sees with what is recorded by a DSLR camera. A dark-adapted human eye will usually pick up some foreground detail while the aurora appears as a faint and slow moving green-greyish 'wisp'. In a strong auroral event, muted activity can quickly change into a very bright and fast-moving display, which can easily overexpose the shot. In this case it's best not to lower the ISO; instead increase the shutter speed.

With the shot captured, I run through the following processing steps in Photoshop, but they will also apply to other layer-based editing software, such as GIMP. The aim is to draw out the best from the foreground while retaining the essential components of the aurora against a dark sky.

[1] With the RAW image open in your editing software (there's a plugin for Photoshop called Camera Raw), first look at the image's colour temperature. Aurorae can totally confuse a DSLR's colour balance, so adjust the colour temperature until the scene better resembles what it looked like on the night. Note the temperature slider compensates for the colour temperature of light: telling it that the light is more blue makes the resulting image more yellow. As with all processing, use small adjustments.

[2] Address the general darkness by raising overall Exposure by about +1, depending on the correction needed, then adjust Whites by about +10. I add a touch (about +5) of Clarity and Vibrance too.

[3] In Camera Raw's Sharpening and Noise Reduction panel, set Sharpening and Luminance to around 50; adjust this higher or lower as needed.

[4] Open the image in Photoshop proper to deal with any underexposed foreground subjects in the image. Mask any foreground with the Magic Wand or Lasso, adding feathering to the edge.

[5] Using Levels or Curves, select the greyscale eyedropper. Dab this on the area of the masked image where the tonal value is approximately 50 per cent. If this produces a bizarre result try another part of the masked image (you can always cancel and start again). Keep going until the resulting image has a natural tonal colour. Adjust the values of the right-hand (white) and middle (grey) sliders until the foreground is revealed to an extent that would be natural to the human eye at night.

[6] Now invert the mask and use Levels or Curves to lighten or darken the sky until it has a natural appearance, remembering that black skies look unnatural. Gently brighten the aurora to suit.

[7] Adjust Hue/Saturation. Select Greens from the drop-down menu and use the colour picker to sample any aurora present. Adjust the sliders until it has a natural colour.

[8] Finish up with some noise reduction: I use Dfine 2, part of the Google Nik Collection of Photoshop plugins.

James won the APY 2014 competition with an aurora image. See more at www.500px.com/imagesinspiredbynature

ALL PICTURES: JAMES WOODEND

Scope DOCTOR

With Steve Richards

Our resident equipment specialist cures your optical ailments and technical maladies

A mono CCD requires external filters (top) but allows you to use narrowband filters for nebulae, unlike a colour CCD (bottom)

I'm a DSLR user but I'm thinking of trying a CCD camera for the first time. What are the pros and cons of colour vs mono? JIM LECKIE

As you own a DSLR, you will quickly discover the two disadvantages of this type of camera for deep-sky work – the attenuation of light in the all-important red portion of the spectrum and thermal noise generated as the sensor warms up during long exposures. A cooled CCD camera will alleviate both of these issues.

Both monochrome and colour CCDs use the same kind of sensor, which detects the intensity of all light that falls upon it. To create an image, the colour CCD uses a matrix of red, green and blue filters overlaid on the sensor's surface so that one colour covers each photosite, or pixel. When the data is processed into an image the colour information is extracted from the matrix, but the interpolation needed between pixels in each colour channel compromises the resolution a little.

When using a mono camera, however, external filters have to be used and the images processed afterwards to create the full-colour result. This method benefits from the increased resolution of using the full CCD at every colour band, but triples the imaging time as you have to take exposures with separate red, green and blue filters.

Mono CCDs can also take full advantage of narrowband filters, whereas colour CCDs always have their colour filters in place, dramatically reducing the signal in three of every four photosites.

The biggest advantage of a colour CCD camera is that unlike a mono CCD and filters, every subframe produces a colour image. Under the unpredictable skies of the UK, this greatly increases the chances of capturing a colour image from each session.

STEVE'S TOP TIP

How do I work out how much data to capture when deep-sky imaging?

Stacking multiple images of deep-sky objects increases the 'signal to noise ratio', which means that you end up with more of the signal you want and less of the noise that you don't want. Setting a limit of around 30 subframes is a good rule of thumb as increasing past this number gives diminishing returns. However, there is no substitute for incorporating long exposures even when stacking, but there are limits here too: imposed by your mount's tracking abilities and by having to ensure that you take short enough exposures for them not to be overwhelmed by light pollution.

Spacing makes combining a DSLR with a focal reducer tricky

Can I achieve focus using a Canon EOS 550D DSLR on a 9.25-inch Celestron Schmidt-Cassegrain with a focal reducer and off-axis guider? ADAM DELMAGE

Installing a camera on a telescope sounds great but as soon as you introduce a focal reducer and an off-axis guider you run into spacing issues. Focal reducers and field correctors have very specific spacing requirements and getting a good match is often fraught with difficulty.

The Celestron off-axis guider cannot be used with an Edge HD Schmidt-Cassegrain, focal reducer and a DSLR camera as the spacing is super-critical and there simply isn't enough backspace allowance for these accessories. However, Celestron's standard 9.25-inch Schmidt-Cassegrain and focal reducer are a little more forgiving.

Although the optimum spacing of the sensor from the face of the focal reducer is 105mm, you can extend this and achieve focus. The components should be installed in the following order: f/6.3 reducer; Schmidt-Cassegrain adaptor; off-axis guider body; male M42 camera adaptor; EOS T-Ring; DSLR.

Steve Richards is a keen astro imager and an astronomy equipment expert

Email your queries to scopedoctor@skyatnightmagazine.com

Sky at Night MAGAZINE

Reviews

Bringing you the best in equipment and accessories each month, as reviewed by our team of astro experts

HOW WE RATE

Each category is given a mark out of five stars according to how well it performs. The ratings are:

★★★★★ Outstanding
★★★★★ Very good
★★★★★ Good
★★★★★ Average
★★★★★ Poor/Avoid

90
William Optics Star 71: a compact scope expressly intended for imaging

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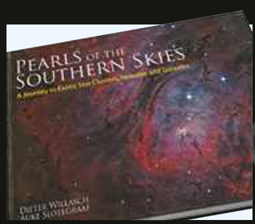
This month's reviews





Find out more about how we review equipment at **www.skyatnightmagazine.com/scoring-categories**

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FIRST **light**

See an interactive 360° model of this scope at **www.skyatnightmagazine.com/willops715**

William Optics Star 71 five-element apo refractor

A compact imaging scope that offers great sharpness and colour

WORDS: PAUL MONEY

VITAL STATS

- **Price** £799 (introductory offer)
- **Aperture** 71mm (3 inches)
- **Focal length** 350mm (f/4.9)
- **Optical design** Five-element patented lens arrangement
- **Tube length** 324mm dew shield retracted, 356mm extended
- **Focuser** 2.5-inch dual-speed rack and pinion
- **Weight** 2.05kg; 2.4kg with tube rings and Vixen bar
- **Extras** Dew shield, tube rings, Vixen dovetail bar, Canon DSLR adaptor
- **Supplier** The Widescreen Centre
- **www.**widescreen-centre.co.uk
- **Tel** 020 7935 2580

Ever since the days of Galileo, the refractor has been the most familiar form of telescope to anyone thinking of exploring the night sky. Early refractor designs suffered from a variety of optical problems, especially when used for astrophotography – and so today manufacturers strive to perfect the ideal imaging refractor. It is this ambition that has led to William Optics's Star 71 five-element apo instrument.

The package comprises an optical tube, tube rings with a Vixen dovetail bar, 2.5-inch dual-speed rack and pinion focuser with built-in thermometer, front and rear metal covers and an M48-Canon EOS adaptor ring. If you have a non-Canon DSLR, you'll need to buy a suitable adaptor.

Cheap refractors suffer from chromatic aberration, a defect where not all colours are brought to the same focus, as well as field curvature. Combined, these lead to distorted star shapes at the edge of the image field of view. Visually a doublet design can improve chromatic aberration, but triplet lenses are often used in scopes intended for imaging as they provide a higher degree of colour correction. Overall triplets work well, but still leave fast apo refractors with some field distortion around the edges.

SKY SAYS...
Stars were sharp to the edges as we'd expect from a scope designed specifically for a flat field

Flat out success

One way to fix this problem is to buy an external flat-field corrector. William Optics has gone even better here, opting for a five-element arrangement: a triplet as the front objective and two correcting lenses, one of which is flat field.

As the Star 71 is expressly intended for imaging, the back of the focusing unit ends in a male M48 thread – which means you can't add a regular star diagonal for visual observing. William Optics has stated that it will be stocking a custom 1.25-inch 90° dielectric mirror diagonal to allow visual use, but this was not available in the UK at the time of review. However we did discover we had a suitable adaptor that allowed us to attach an eyepiece for straight-through viewing with our own 26mm and 17mm eyepieces.

The Vixen mounting bar has a tripod thread, allowing us to attach the scope to a standard tripod. We enjoyed crisp wide field views with our 26mm ▸

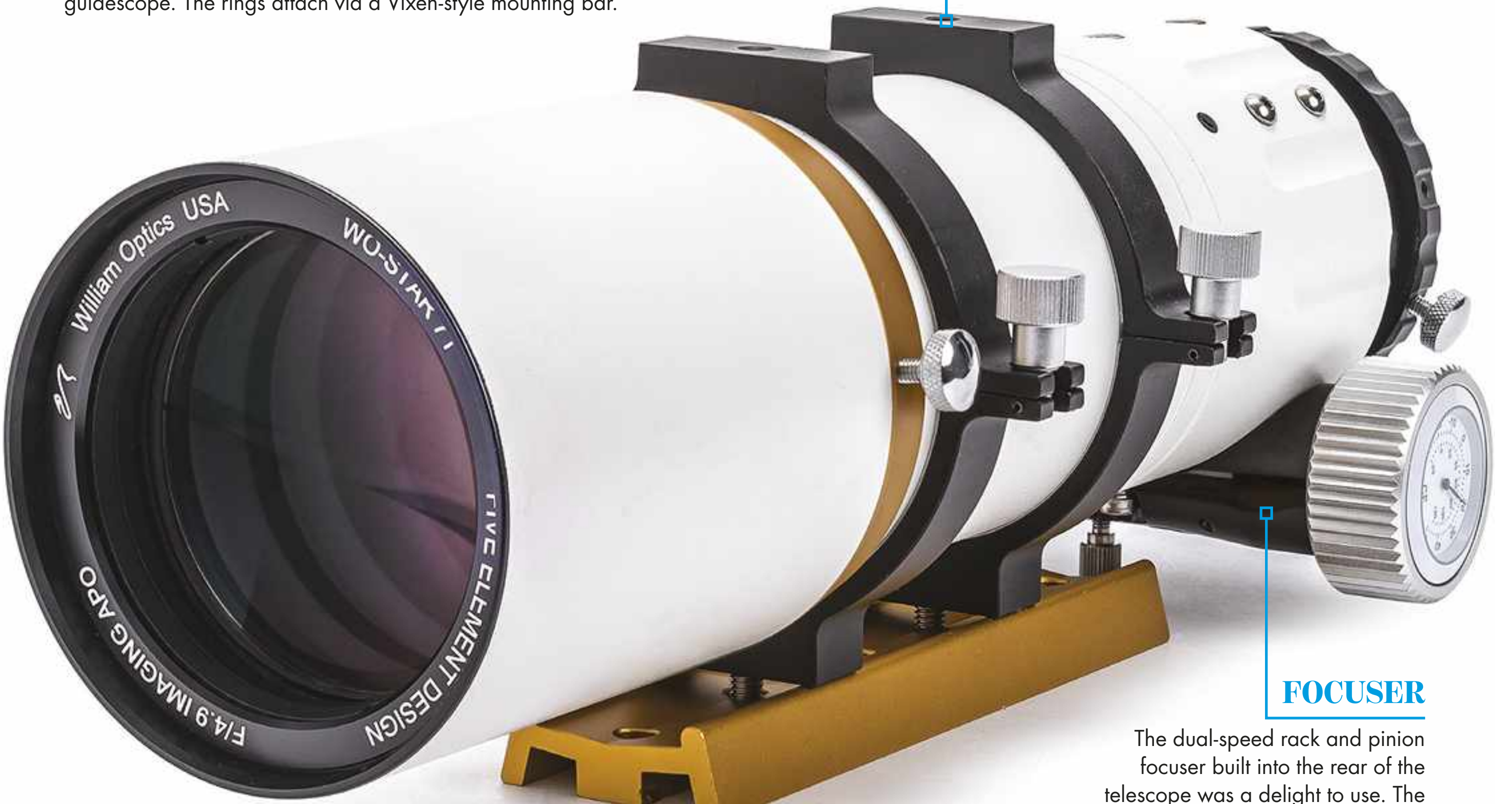
SLIGHT AND LIGHT

The combination of compactness and lightness, even with the tube rings and Vixen dovetail bar attached, make this a viable travel telescope as well as one that can capture great wide-field vistas. The telescope tube weighs just 2.05kg; even with the ring and dovetail bar attached it's only 2.4kg, and at 324mm long it can fit in airline hand luggage. Its size and weight makes it suitable for any of the travel mounts reviewed in these pages, enabling you to take it abroad to capture large deep-sky objects that are not visible from your regular observing sites. Add to that the excellent colour, field correction and fast focal length, and you'll find that lots of short image exposures of a minute or so will give great results.

WWW.THESECRETSTUDIO.NET X 4, PAUL MONEY X 2

TUBE RINGS AND VIXEN BAR

The scope is supplied with a sturdy and nicely crafted pair of tube rings, which are lightweight and easy to use. There are threaded holes on the top of each one so that you can add other accessories, such as a guidescope. The rings attach via a Vixen-style mounting bar.



FOCUSER

The dual-speed rack and pinion focuser built into the rear of the telescope was a delight to use. The screw at the base enables you to lock the focus position and didn't move even with our DSLR attached, though there was a tiny image shift when initially locking it.

DEW SHIELD

The retractable dew shield was smooth to use, being easy to retract for storage and capable of being locked in place with a thumbscrew. Though the shield seemed a little short, it gave good protection from dewing up under normal conditions.

▲ Our four-minute hydrogen-alpha exposures revealed the Veil Nebula Complex in its entirety save for a faint region in the western section

▲ Our final stacked images of the Pleiades in Taurus showed a healthy amount of nebulosity as well as the cluster stars themselves

FIRST light

OPTICS

The patented five-element design incorporates a multicoated triplet objective lens at the front and two further lenses farther down the tube to provide additional colour and field correction. The lenses made of FPL-53 low-dispersion glass for colour-free apochromatic performance.

INTERNAL BAFFLES

There are internal baffles at both ends and these are coated with matt paint to cut down on stray light bouncing around inside the tube. They do a good job in preventing internal reflections, which would otherwise spoil the contrast of faint deep-sky objects.

▸ eyepiece and slightly more magnified views with the 17mm. Stars were sharp to the edges as we'd expect from something designed specifically for a flat field; there's every indication that with the custom diagonal the Star 71 can be turned into a visual instrument if you so wish.

But this is primarily an imaging instrument so we attached our Canon EOS 50D DSLR to the scope and set them on an NEQ6 Go-To mount, giving us the ability to capture exposures of up to four minutes without guiding. The camera's APS-C sensor, coupled with the Star 71, equates to an image scale of 3.65° by 2.4°, a nice wide field of view. Full format camera sensors will give an even wider view of 5.9° by 3.9°, which is large enough to photograph sprawling targets such as the Veil Nebula and Andromeda Galaxy comfortably.

We imaged the Pleiades star cluster, taking a series of exposures of 30 seconds each to ensure no trailing. Stars at the corners were still crisp and well rounded with no sign of distortion. The final stacked image, made from two sets of data on different days, showed an enjoyable amount of nebulosity too. We also experimented with taking hydrogen-alpha images of the Veil Nebula Complex, partly because of moonlight and partly due to the scale of the object. We achieved 12 exposures of four minutes each at ISO 3200, showing the whole complex bar a fainter section of the western section.

Overall, William Optics has produced a good looking, compact imaging telescope that gives sharp stars out to the field edges and good colour correction. We can recommend it to anyone interested in wide-field imaging. S

WWW.THESECRETSTUDIO.NET, PAUL MONEY X 2

◂ Our composite of the Beehive Cluster, made from 20 exposures lasting 60 seconds

◂ The Star 71 has a field of view of 3.65° by 2.4° – so targets such as the Moon appear quite small

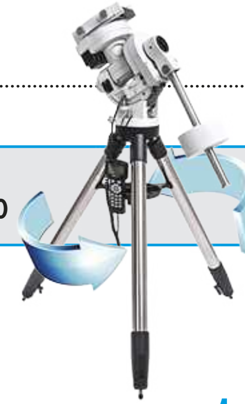
VERDICT

BUILD & DESIGN	★★★★☆
EASE OF USE	★★★★★
FEATURES	★★★★☆
IMAGING QUALITY	★★★★★
OPTICS	★★★★★
OVERALL	★★★★★

SKY SAYS...
Now add these:
1. Soft case
2. 50mm guidescope and rings
3. William Optics 1.25-inch 90° dielectric mirror diagonal

FIRST light

See an interactive 360° model of this mount at
www.skyatnightmagazine.com/iopmountcem60



iOptron CEM 60 equatorial mount

A surprising Z-shaped mount that offers novel solutions to common problems

WORDS: STEVE RICHARDS

VITAL STATS

- **Price** £2,299
- **Payload capacity** 27.2kg
- **Hand controller** Go2Nova 8407 with 32-channel GPS
- **Database** 358,000 objects
- **Flash upgradeable** Yes
- **Autoguider port** Standard ST-4
- **Extras** Flight case, polarscope, 12V cigar lighter cable, AC power supply, serial cable, 9.5kg counterweight
- **Weight** 12.3kg (excluding counterweight)
- **Supplier** Altair Astro
- **www.**altairastro.com
- **Tel** 01263 731505

Astronomers want all sorts of things from a telescope mount, but nothing is more challenging than the quest for good stability allied with lightness. The CEM 60 tackles these conflicting needs head on with its unusual Z-shaped design.

The mount is supplied in a substantial, internally sculpted aluminium flight case. This case is such an excellent fit that it ensures the safe delivery and later transport of the mount. Paradoxically for a mount so clearly capable of portability, the tripod is an optional extra – although in fairness many of these mounts will be bought for installation on piers in home observatories. The tripod depicted here was loaned to us for the purposes of this review.

The offset Z shape of the CEM 60 looks very different to other equatorial mounts and at first glance it is not immediately obvious how it works. Closer inspection reveals that this novel design results in the RA axis being substantially supported in main bearings at two locations. Placing the mount load between two bearings in this manner should produce a better mechanical solution than the usual mounting method that has the bearing to one side of the payload.

SKY SAYS...
We were very impressed with how quiet the mount was when slewing. Your neighbours won't hear this one

The counterweight bar is offset from the centre line, completing the Z shape. Achieving an accurate balance in both the RA and dec. axes is easy, because once the clutch mechanism is disengaged both axes rotate fluidly.

Unusually, the mount head sits in a pair of crescent-shaped cups on the top of the base section and is retained in position by a pair of small locking capstans. This simple arrangement allows the whole mount to rotate easily for altitude adjustment.

The supplied Go2Nova 8407 hand controller has a full feature set and a database of over 358,000 objects. It has an internal 32-channel GPS receiver that supplies date, time and location information automatically and it took less than 45 seconds to initialise at the start of each of our observing sessions.

Priming the mount

A good polar alignment is a prerequisite for accurate slewing and the Go2Nova has two methods to help you achieve this. The first produces a graphical display showing the position of Polaris in relation to the north celestial pole. Simply rotate the RA axis until the bubble level on the polarscope is centred, then adjust the altitude and azimuth of the mount to place the view of Polaris in a matching position ▸

DEFINED BY DESIGN

The CEM 60 is the second of iOptron's unusual Z shaped designs, the first being the company's smaller ZEQ25 GT mount. This design is currently unique to iOptron.

An important design element of this mount is that it keeps the centre of gravity directly over the centre of the tripod and as low as possible, giving natural balance and increased stability. With the RA axis supported at both ends, this allows a rugged mounting to be produced without the bulk and additional materials of a more conventional design. This makes the CEM 60 easy to transport but also capable of a high payload capacity of 27.2kg. These virtues make the mount a good choice for portable astrophotography where a good payload capacity and sturdiness are very appealing.

As the counterbalance shaft is offset and bolted onto the RA housing rather than inserted through it, the polarscope sighting tube is never obstructed thus allowing unrestricted access to the polarscope.

SPRING-LOADED SADDLE CLAMP

The saddle clamp is compatible with both the standard Vixen and the larger Losmandy styles of dovetail bar. A generous 114mm clamping section ensures a firm but non-marring attachment for your telescope. Twin spring-loaded hand bolts allow easy tightening even when wearing gloves.

ALTITUDE ADJUSTMENT

Altitude adjustment, which must be carried out to ensure an accurate polar alignment, uses a geared quadrant driven by a worm screw. We found this very easy to adjust and much simpler than the usual opposing bolt method adopted in many other mounts. Two locking capstans clamp the mount firmly in position.

HAND CONTROLLER

The Go2Nova 8407 hand controller has a generous eight-line display and integrated temperature control. With a huge database of in excess of 358,000 objects – including Solar System, NGC, Messier, Caldwell, Herschel 400, UGC, IC, GCVS, Abell, binary stars and the SAO catalogue – there's no shortage of objects to locate and observe.

FIRST **light**

GEAR SYSTEM

To minimise any backlash in the worm gear drive system, the CEM 60 uses a magnetically loaded gear system to maintain a constant mesh. An unusual clutch mechanism comprised of a small adjustment knob allows for free rotation of each axis for balancing purposes, but a solid engagement when locked.

CONNECTIONS

To assist with cable management, the CEM 60 has a range of extended ports mounted on the rear of the dec. axis head. There are four USB 2.0 sockets, two 12V power sockets and an ST-4 autoguiding port. Connections to a computer and 12V supply are on the panel surrounding the polarscope.

▸ to the display. For southern hemisphere use, Sigma Octantis takes the place of Polaris. The second method, called 'BrightStar', doesn't require a view of Polaris – it is an iterative process requiring one star at high altitude and another near the horizon. The azimuth adjustment, using two posts and bolts on either side of the mount, was simply a joy to use.

Following polar alignment there is a choice of one-star or multi-star alignment. Using the latter option with three stars we found Go-To accuracy to be excellent, with our chosen objects across the sky appearing within our 17mm eyepiece. Accuracy can be further improved by choosing up to nine stars for the alignment.

We were also very impressed with how quiet the mount was when slewing at full speed. Your neighbours won't hear this one. And when it came to imaging, we captured five- and 10-minute guided exposures using our 98mm refractor with an off-axis guider and were delighted with the very round stars that we recorded. The mount was certainly easy to guide using the industry standard ST-4 port for control.

The CEM 60 mount should be on any intermediate user's shortlist and we would particularly recommend it for astrophotography, a situation where payload capacity and stability are so important. S

WWW.THESECRETSTUDIO.NET X 3

VERDICT

ASSEMBLY	★★★★☆
BUILD & DESIGN	★★★★☆
EASE OF USE	★★★★☆
GO-TO ACCURACY	★★★★★
STABILITY	★★★★★
OVERALL	★★★★☆

SKY SAYS...
Now add these:

1. Altair Starbase field tripod (for travel)

2. Altair Adjustable 8-inch observatory pier (for home use)

3. Additional counterweights

FIRST **light**

See an interactive 360° model of this camera at
www.skyatnightmagazine.com/inovacx

iNova NNB-Cx colour CCD camera

A rare breed that bridges the divide between planetary and deep-sky imaging

WORDS: PETE LAWRENCE

VITAL STATS

- **Price** £455
- **Sensor** Aptina MT9M034, 8.5mm (1/3-inch), 1280x960 3.25μm pixels
- **Ports** USB 2.0, ST-4 (autoguiding), TTL (peripheral control)
- **Operating systems** Windows XP (SP3), Vista, 7, 8 and 8.1 (32 & 64-bit)
- **Fitting** C-mount, 1.25-inch adaptor supplied
- **Size** 90x76x48mm
- **Weight** 260g
- **Supplier** SCS Astro
- **www.**scsastro.co.uk
- **Tel** 01823 665510

WWW.THESECRETSTUDIO.NET X 5

The iNova NBB-Cx colour camera blurs the line between planetary and deep-sky imaging, which for a long time have been regarded as two distinct disciplines. There are a number of cameras already on the market that can be used to image both, but the NBB-Cx goes the extra mile by including active cooling to reduce noise and produce optimised results.

The phrase 'Solar System imaging' describes the processes required to capture images of the Sun, Moon and brighter planets. These targets are relatively bright, but suffer because the fine detail they present is at the mercy of the Earth's turbulent atmosphere and easily lost. Planetary cameras such as the NBB-Cx address this issue by taking lots of short exposure still images in a short burst. By picking out the best frames, then aligning and stacking them, its possible to remove noise. The smoother end result is then suitable for further processing to bring the best out of the image.

The NBB-Cx is great at this. Its capture software, PLxCapture, offers a dedicated planetary imaging module capable of capturing 8- or 12-bit images with exposures between one and 1,000 milliseconds. The camera's Aptina MT9M034 sensor has a 1280x960 pixel array, which is ideal for capturing large areas of the Moon or Sun. At full array size, the camera is capable of delivering 8-bit frames at 30 frames per second (fps).

SKY SAYS...
It's a decent planetary imager and certainly capable of taking great deep-sky images

A planet's disc will typically occupy a small part of the imaging field, and so the camera allows you to select a region of interest (ROI), using a smaller portion of the sensor. A smaller pixel array means less data and consequently a higher frame rate – and capturing more frames per second gets your more from periods of steadier seeing. The smallest ROI of 320x240 pixels can be delivered at 200fps.

Colouring the night

Our lunar imaging session produced excellent results despite the Moon's low altitude at the time, with post processing revealing some fine detail. An early morning session on Jupiter showed off the colour capabilities of the camera, the red-brown Southern and Northern Equatorial Belts contrasting beautifully with the exquisite grey-blue of a large equatorial festoon. ▸

Thermoelectric cooling (TEC) unit

A COLD-HEARTED BEAST

The NBB-Cx camera has a number of optimisations to help improve image quality. For a start, the thermoelectric cooling (TEC) unit uses a Peltier circuit and a cooling fan to achieve a temperature at least 25°C below ambient levels. Cooling fins on the camera body speed up heat removal and these get appreciably warm to the touch quite quickly.

The sensor cooling makes a noticeable difference to the thermal noise present in images, something that increases as you up the exposure time. In addition, during long-exposure sessions, non-essential components inside the camera are powered down, further reducing sources of heat and delivering images that are less noisy as a result.

Another unwanted noise source, known as readout noise, occurs every time an image is read off the sensor and pixel charge converted to a digital value. The NBB-Cx camera helps reduce the effects of readout noise by providing different sensor readout speeds for its imaging modes. Finally, the visual enhancement deep-sky imaging module produces the cleanest long-exposure images by incorporating real-time stacking to average out random noise.

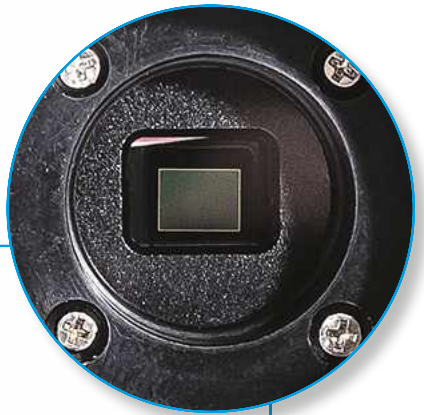


IMAGE SENSOR

Light is recorded by an Aptina MT9M034 CMOS colour sensor with a full array of 1280x960, 3.75μm pixels. The chip's quantum efficiency is good across visible wavelengths (red 57 per cent, green 62 per cent, blue 51 per cent); quantum efficiency being a measure of how much incoming light is actually recorded. It can also be 2x2 binned for greater sensitivity. An infrared-blocking filter is pre-fitted.

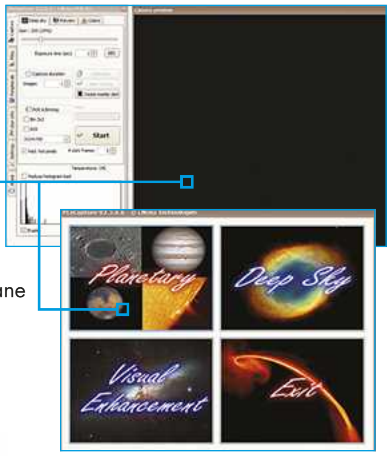
AUTOGUIDING PORT

As well as its imaging capabilities, the iNova NBB-Cx can be used for autoguiding. An RJ12 ST-4 cable (not supplied) is required to connect the camera to a compatible mount. An ASCOM driver allows the camera to work with a number of commercial packages as well as popular freeware programs.

COMMUNICATIONS PORT

The communications port at the base of the camera can be used to control other equipment via the ASCOM platform. Control can then be applied via the PLxCapture software for equipment such as electric focusers, motorised filter wheels and GPS units.

FIRST light



PLXCAPTURE SOFTWARE

The camera is controlled via PLxCapture. On start up this presents four clickable areas, giving access to the Solar System, deep-sky and visual enhancement interfaces; a fourth pane exits the program. Each interface is similar in appearance offering settings appropriate to what you're imaging. The visual enhancement module stacks deep-sky images in real time.

C-MOUNT/1.25-INCH FITTING

The camera is pre-threaded with a C-mount thread, a standard often used for video cameras. A C-mount to 1.25-inch eyepiece adaptor is supplied as standard.

▸ When you're done imaging Solar System objects, the NBB-Cx can turn its hand to deep-sky targets. Here, the requirements of the camera change somewhat: the very short exposures needed for planetary work are replaced with long exposures necessary to record faint detail in nebulae and galaxies.

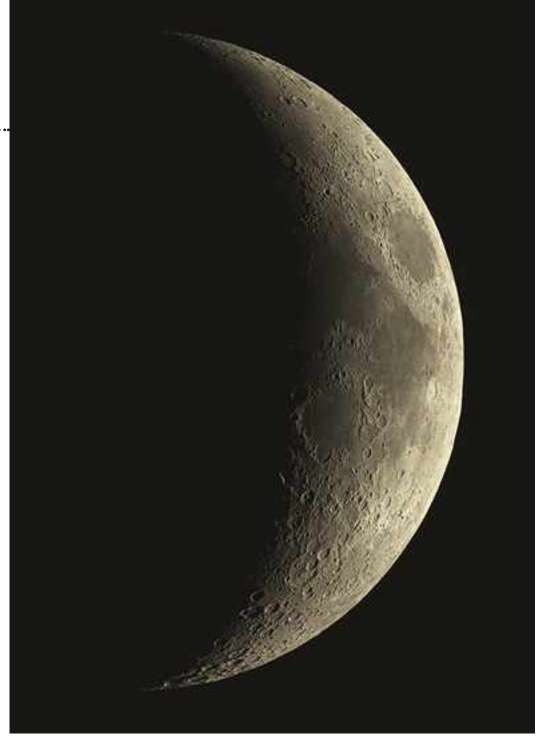
Our first test sequence was on the Orion Nebula, M42. We captured some great detail using a 4-inch f/9 telescope and modest exposures of 30 seconds and 120 seconds. The results showed plenty of red too, which is an important component colour of emission nebulae. Star colours were generally excellent as well; we managed to image bright Aldebaran in Taurus with its distinct orange hue intact.

The camera's operating software is supplied on a USB memory stick and includes all you need to get the device working. Installation is straightforward but it pays to read and follow the initial instructions carefully. Camera control is via PLxCapture, which offers separate interfaces for planetary imaging, deep-sky imaging and visual enhancement. The design of each interface is reassuringly similar. Each presents two windows, one for control and one showing a preview of what the camera is seeing.

There are various noise reduction optimisations available with this camera, and they all work at their best when using PLxCapture's visual enhancement module. This is designed to create the cleanest images by stacking them in real time. The visual enhancement module also includes its own autoguiding functions.

This camera performed well for us and was fun to use. It's a decent planetary imager and certainly capable of taking some great deep-sky images, especially when coupled with a short focal length wide-field scope. If you're just starting out, its main attraction is that it covers two bases in one device. The use of similar looking controls for both disciplines is a big plus point too. Finally, the addition of autoguiding functions means that should you upgrade in the future, the NBB-Cx still has a valuable place in your equipment toolbox. Ⓢ

SKY SAYS...
Now add these:
1. iNova Carbon fibre 70 ED refractor doublet
2. Sky-Watcher Star Adventurer mount
3. iNova lithium-ion battery pack 12V – 9.8Ah



▲ We created this lunar mosaic with shots taken through a 4-inch refractor while the Moon was at low altitude

▲ Combined 30- and 120-second exposures of M42's core – see page 60 for more tips on imaging this nebula

▲ Through a C14, we captured great contrast on Jupiter, where dark belts nestled alongside a grey-blue festoon

VERDICT

BUILD & DESIGN	★★★★★
CONNECTIVITY	★★★★☆
EASE OF USE	★★★★☆
FEATURES	★★★★☆
IMAGING QUALITY	★★★★☆
OVERALL	★★★★☆

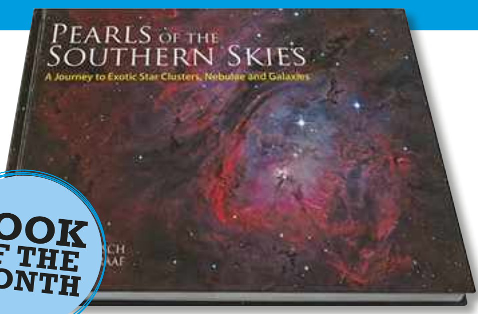
Books

New astronomy and space titles reviewed

RATINGS
★★★★★ Outstanding
★★★★☆ Good
★★★☆☆ Average
★★☆☆☆ Poor
★☆☆☆☆ Avoid

You can order these books from our shop by calling 01803 865913

Pearls of the Southern Skies



BOOK OF THE MONTH

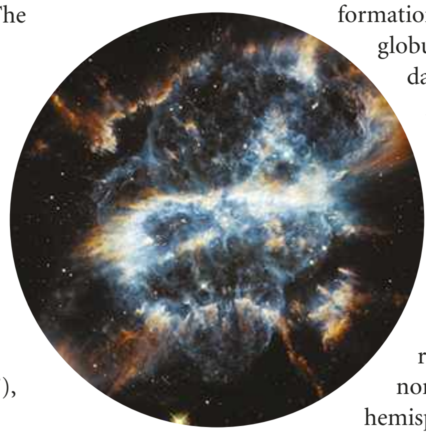
Dieter Willasch and Auke Slotegraaf
Firefly
£24.99 ● HB

At first glance, you could easily mistake this book showcasing the wonders of the southern hemisphere skies for yet another coffee table tome full of pretty pictures. But although there are numerous superb images within its pages, the accompanying text makes it a fascinating read as well.

Translation from the original German version is very good and the object descriptions are written in an engaging style that leads you to examine each image more closely and specific features mentioned in the text. The objects are arranged in right ascension order – an excellent format for helping to approximately determine the best time for observation. Information about the 71 objects includes common names (including some uncommon 'nicknames'), catalogue designations, coordinates, object type, size and the orientation of the image. Of particular interest to astrophotographers is an appendix at the end of the book that details the equipment used and exposure times for each image – this is a real astronomer's book.

The page format places a beautiful quality image on the left-hand page with the text on the right but, where appropriate, a smaller wide-field image is included to show an object in its 'natural surroundings'. This approach works very well, especially for objects embedded within other objects or where a main feature of a more extensive nebula has been highlighted. The images are beautiful and have been taken using a range of filters to bring out fine detail. Many are composited from both wideband (LRGB) and narrowband (Ha and OIII) data, a technique that is becoming very popular.

To add further to the descriptive text, there are well written articles towards the back of the book describing the formation of stars, open clusters, globular clusters, bright and dark nebulae, planetary nebulae and supernova remnants, finishing with galaxies and galaxy clusters. These make an excellent introduction to an astronomy beginner and are, of course, relevant to both northern and southern hemisphere objects.



Southern hemisphere nebula NGC 5189 in the constellation of Musca

NASA/ESA AND THE HUBBLE HERITAGE TEAM (STSCI/AURA)

Observers in the northern hemisphere cannot see many of the southern hemisphere objects depicted here. If you have a natural fascination about observing them, this excellent photographic digest will fuel that curiosity.

★★★★★

STEVE RICHARDS *is* BBC Sky at Night Magazine's *Scope Doctor*

Reader price £22.99, subscriber price £21.99
P&P £1.99 Code: S0115/4 (until 23/02/15)

TWO MINUTES WITH AUKE SLOTEGRAAF

What inspired you to write the book?
My good friend Dieter Willasch has been imaging the southern sky for many years. His archive of beautiful photographs was the impetus to put together this volume. Our intention was that the book should showcase images of the 'best' southern hemisphere objects while also giving some context to each one by describing its visual appearance, history and basic astrophysical characteristics.

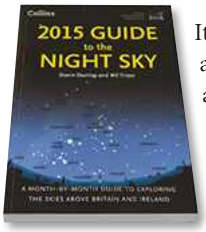
What makes the southern sky so beautiful?
There are two features I think: the first is the magnificent view of the centre of our Milky Way. To see the Scorpion and the Archer overhead with the Milky Way stretching down to the horizon creates an indelible impression. The other is the duo we call the Cape Clouds, better known as the Large and Small Magellanic Clouds. Naked-eye targets from a dark site, they present telescopic observers with a wonderful challenge because of the sheer number of objects they contain and diverse visual appearance.

How did you choose your favourites?
Once we had selected the core list, we sorted through Dieter's archive for other eye-catching images. We also compiled a list of objects that would be of interest to deep-sky observers. Dieter spent several sessions imaging some objects specifically for the book. We eventually ended up with enough material for a very big book indeed, but the painful process of ruthlessly pruning objects was inevitable.

AUKE SLOTEGRAAF *is director of the Deep Sky Observing Section of the Astronomical Society of South Africa*

2015 Guide to the Night Sky

Storm Dunlop and Wil Tirion
Collins
£6.99 ● PB



It is a sheer delight to find a book that completely and seemingly effortlessly achieves its aims. The *2015 Guide to the Night Sky* combines clear and economical writing with charts drawn by an accomplished uranographer to guide readers, month by month, through the significant celestial events of the year.

After a concise explanation of key concepts, the major northern constellations are introduced as reference markers from which the rest of the sky can be explored. The book is mainly concerned with phenomena that can be observed with the naked eye. For each month, there are charts of the northern and southern skies, Moon phases, the ecliptic and notable events such as appulses (close approaches) of bright planets, stars and the Moon. The ecliptic charts show the motion of the Sun and bright planets. There is also a calendar that lists Moon phases, appulses, meteor shower maximums, planetary oppositions, conjunctions and elongations (all of which are explained in the introduction) and other astronomically important events.

There are descriptions of what may be seen from Britain in the northern and southern skies, meteor showers and phenomena concerning the Moon and planets. Alongside these are notes of some significant events – ranging from the unobservable, such as the Dawn mission to Ceres, to the unmissable, such as March's solar eclipse and September's lunar eclipse.

If you are stuck for a gift idea for any observational astronomer, but especially a newcomer to the hobby, give them this book. They will not be disappointed.

★★★★★

STEPHEN TONKIN *writes our* Binocular Tour *each month*

Reader price £5.99, subscriber price £5.50
P&P £1.99 Code: S0115/1 (until 23/02/15)

Incoming Asteroid!

Duncan Lunan
Springer
£35.99 ● PB

What if we knew Earth would be hit by an asteroid in a decade's time? Would we cross our fingers and hope not to die, or tackle the threat head on? If we decided on action, what could we do?

These questions underpin Duncan Lunan's book on an impact preparation project at ASTRA, an organisation that began life as the Scottish arm of the British Interplanetary Society.

Incoming Asteroid! establishes that there is a real threat and explains how we could best detect and prepare for an impact. There are three main methods we could use to avoid a disastrous dinosaur-like fate: deflecting the asteroid using remote probes, launching a manned mission to nudge the asteroid onto a different orbit or blowing it up with nuclear weaponry.

Lunan touches on how humanity would deal with an impact – preventing mass chaos, surviving and returning to normality. If unprepared, up to 25 per cent of the human population would die from a collision with a 1km-wide asteroid, says Lunan. With planning, this could drop below five per cent.

The topic is interesting, but Lunan does not do it justice for a general audience and *Incoming Asteroid!* is not always enjoyable to read. At times it seems like an advert for ASTRA's programme and is occasionally quite one-sided, strongly pushing certain perspectives and dismissing criticisms readily. The excessive references are also a distraction – by page 20 the count had already hit 47 – and the story derails frequently as the author becomes bogged down in small details. For those interested in the ASTRA project rather than the general topic, it is a comprehensive overview.

★★☆☆☆

NICKY JENNER *is a science journalist and Hubble public information officer*

Reader price £33.99, subscriber price £29.99
P&P £1.99 Code: S0115/2 (until 23/02/15)

You Are Here

Chris Hadfield
Macmillan
£19.99 ● HB

Chris Hadfield is the nearest thing to a celebrity among the modern breed of astronaut. Canada's famous spaceman, instantly recognisable thanks to his equally famous moustache, made great use of social media to promote his last mission to the International Space Station from December 2012 to May 2013.

He delighted fans, of course, with a new rendition from orbit of David Bowie's pop classic Space Oddity, the words adapted to reflect his own mission. But when he wasn't strumming his guitar, or keeping busy with essential tasks on the orbiting outpost, Hadfield liked to photograph the Earth.

He took an astonishing 45,000 photos over 2,597 orbits from his vantage point, some by chance and others meticulously planned to record a particular site. Hadfield posted several on Twitter but now gives us many previously unseen images in this picture-packed book, along with an entertaining commentary.

The book is subtitled Around the World in 92 Minutes, the time it takes to make one orbit. In fact, they were assembled over five months, providing a fascinating and colourful view of our own planet as only a few are ever privileged usually to see it. They include patterns, made by weather, nature and mankind. Some are particularly dramatic, such as asteroid impact scars and volcanoes. Others resemble abstract paintings or, as with Lincolnshire's fields, patchwork quilts.

This beautifully produced package is not a textbook. Rather, it will give a fresh appreciation of the amazing Earth on which we live.

★★★★★

PAUL SUTHERLAND *is a space writer and journalist*

Reader price £18.50, subscriber price £17.50
P&P £1.99 Code: S0115/3 (until 23/02/15)

Gear

Elizabeth Pearson rounds up the latest astronomical accessories

[redacted]

1 Altair Lightwave 3mm Long Eye Relief Planetary Eyepiece

Price £45 • **Supplier** Altair Astro
01263 731505 • www.altairastro.com

Delivering high magnification with a short focal length scope, this 55° field of view eyepiece is ideal for planetary or lunar observing. Other focal lengths are available.

2 Vixen SX 2.1x42 Binoculars

Price £229 • **Supplier** Tring Astro
01442 822997 • www.tringastro.co.uk

Based on Galilean optics, these ultra-portable binoculars offer 2.1x magnification and wide views. A soft carry case is included.

3 Sky-Watcher Enhanced Dual-Axis Drive for EQ5 Mount

Price £110 • **Supplier** f1Telescopes
01795 432702 • www.f1telescopes.co.uk

With Sky-Watcher's enhanced hand controller allowing you to interface with an autoguider, this motor drive helps to ensure that your camera/scope setup tracks with the night sky.

4 Space Origami Set

Price £4.99 • **Supplier** Paramount Zone
020 3384 8304 • www.paramountzone.com

Create your own astronauts, Moon landers and stellar objects with this unique origami set. The pack contains everything you need to recreate the wonders of the Universe using nothing more than coloured paper.

5 Polarscope Illuminator

Price £46.20 • **Supplier** 365Astronomy
020 3384 5187 • www.365Astronomy.com

This illuminator delivers a dim red light to make the marks on the reticle of your polarscope visible. It has been CNC machined to fit mounts that have a polarscope inside the RA axis; go online for a full compatibility list.

6 Philip's Star Map

Price £5.99 • **Supplier** Scopes'n'Skies
03333 440817 • www.scopesnskies.com

This handy wall chart not only helps you find your way around the night sky, but is an attractive addition to any astronomer's home.

WHAT I REALLY WANT TO KNOW IS…
What lit up the Universe?

Andrew Pontzen aims to lift the fog on what produced the ultraviolet light that ended the darkest days of the cosmos

INTERVIEWED BY PAUL SUTHERLAND

"Right after the Big Bang, there was a lot of light because the Universe was very dense and very hot, but as it expanded and got older, it cooled down until it became opaque. Astronomers call this period the Dark Ages.

Around a billion years after the Big Bang, the Universe began to light up again with the generation of intense ultraviolet light as neutral hydrogen was turned into ionised hydrogen. It was a bit like burning away a fog. On a foggy day, it takes a while before you really see the sunlight because all the energy from the Sun first goes into getting rid of the fog. Then eventually it clears and you see the Sun properly.

The Universe went through some stage like that and there has long been a question over how exactly it happened. What burned away that fog? You need an awful lot of light, or to put it another way an awful lot of energy, to make the whole Universe transparent in this way.

The source of the light

Our bid to solve this puzzle is focused on looking back a little more recently, to around 10 billion years ago when the Universe was being bathed in light. We know that was happening because we can actually see distant galaxies as they were at that time. However, it's still not clear what is producing most of the light, or energy. Was it a small number of very bright objects or a large number of individually quite dim objects? It is rather like flying over a country at night. When you look down from your aircraft, you can see either a few really big patches of light coming from big cities or maybe smaller sources of light much more spread out in lesser towns and villages. Either could be producing the same amount of power in total.

Our computer modelling has shown that it should be possible to answer this question by studying data that will be forthcoming from a new sky survey, using a spectroscopic effect called the Lyman-alpha forest. Take something very distant and bright, say a quasar. As its light travels towards our telescope, it encounters lots of gas, and so there is always the possibility that any particular photon, or particle of light, will be absorbed by some of this gas along the route. Combine that effect with the fact that light is redshifting as it comes towards us, due to the expansion of the Universe. It means that when we analyse the light from our distant quasar we get a sort of thumbprint, a very good measure of what is going on in the gas between us and the quasar – that thumbprint is called the Lyman-alpha forest.

The phenomenon has been used before, mainly to put constraints on things such as dark energy because it is tracing the way that structure is behaving in the Universe. But the gas that causes it is also responding to the light being generated in the Universe. So if you compare the thumbprints of millions of quasars, you can get at how patchy the light is in the Universe, which in turn tells us what is actually generating it.

We plan to use a survey coming online in 2018 known as DESI, short for Dark Energy Spectroscopic Instrument, which will be running on a ground-based telescope at Kitt Peak, Arizona. DESI will take spectra of the light from millions of objects, including about a million quasars.

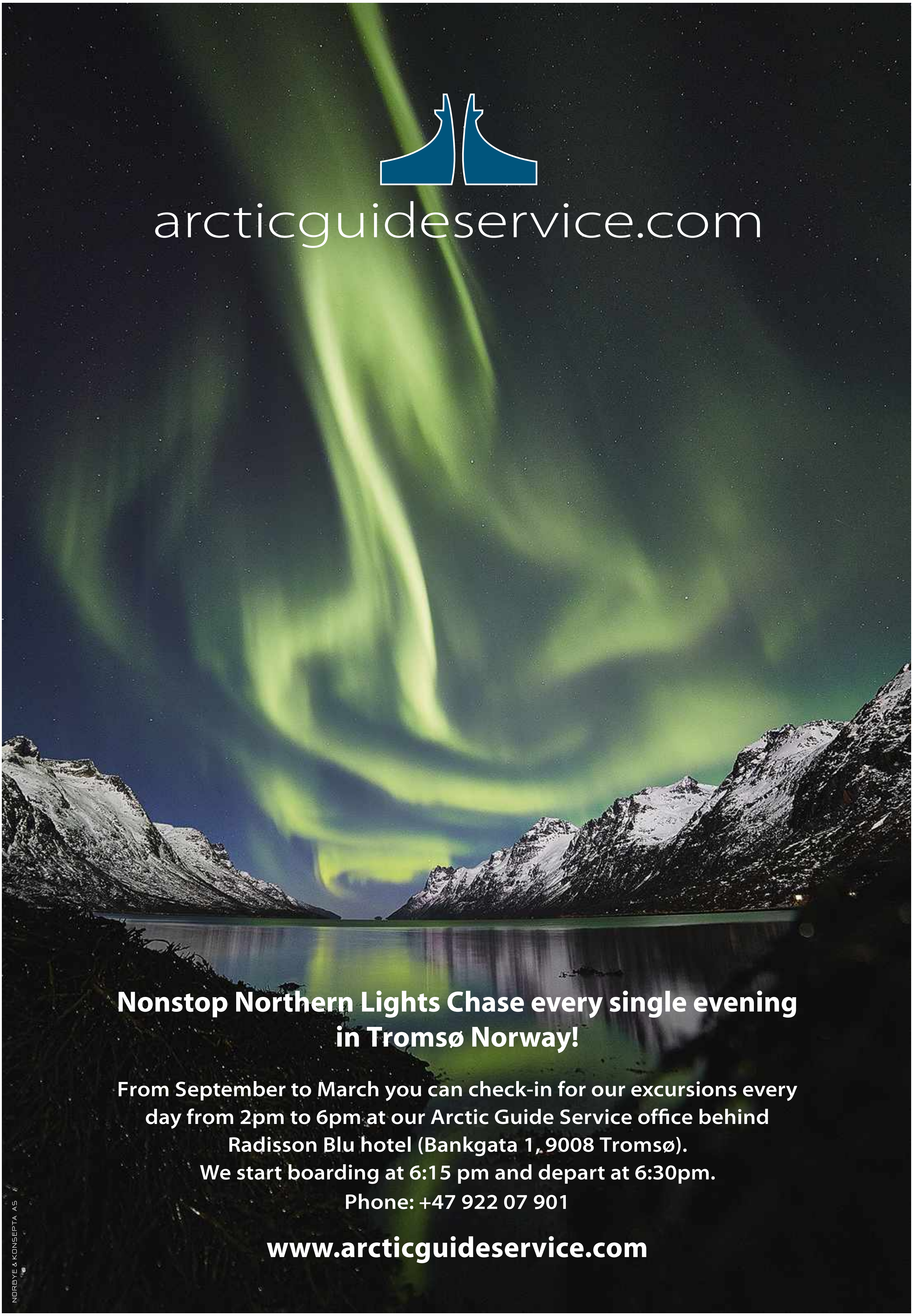
We are pretty hopeful of finding a result, but it will really be a win-win study. Either the patchiness will be there, showing that illumination of the Universe is quite uneven and so from rare bright objects like quasars, or we won't see it, which effectively reveals that the Universe is actually very uniformly illuminated. In that case, the illumination has to be coming from small numerous objects, tiny little galaxies that we would never see individually on their own."

We can see galaxies in the early Universe, but we're not sure what ended the cosmic Dark Ages

ESO/M. KORNMESSER

ABOUT ANDREW PONTZEN

Dr Andrew Pontzen is a researcher at University College, London, where between writing songs he seeks to master the Universe and shed light on its early history.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NORBYE & KONSEPTA AS

The Southern Hemisphere in January

With Glenn Dawes

WHEN TO USE THIS CHART

1 JAN AT 00:00 UT
15 JAN AT 23:00 UT
31 JAN AT 22:00 UT

The chart accurately matches the sky on the dates and times shown. The sky is different at other times as stars crossing it set four minutes earlier each night. We've drawn the chart for latitude –35° south.

JANUARY HIGHLIGHTS

There are some great conjunctions in the evening skies. January opens with Mercury 2.5° to the lower right of Venus in the twilight. Mercury slowly moves towards Venus with closest approach on 11th, when they will be separated by 0.6°. On the 22nd, the crescent Moon forms a triangle with these two inner worlds, being 7° to the right of Venus. The following night the Moon is 5.7° to the right of Mars. On the 8th, the waxing gibbous Moon forms a triangle with Jupiter and mag. +1.4 Regulus (Alpha (α) Leonis).

STARS AND CONSTELLATIONS

Look below Orion in the northern evening sky and spend some time with Taurus. The bull's most distinctive feature is the V-shaped Hyades star cluster, which represents its face, complete with a red eye in the form of mag. +1.0 Aldebaran (Alpha (α) Tauri). Extending the V takes you to the end of its horns, marked by mag. +3.0 Zeta (ζ) Tauri and mag. +1.7 Elnath (Beta (β) Tauri). From the southern hemisphere the constellation is mostly upside down, making its head tricky to visualise.

THE PLANETS

Brilliant Venus can't be overlooked near the western horizon despite spending January embedded in the evening twilight. Mercury is close to Venus for the first two weeks, but then drops into the Sun's glow. Mars and Neptune are heading slowly towards Venus, and by month end they all set around the end of twilight. Uranus follows Neptune and sets about 90 minutes later. Jupiter is visible most of the night, transiting at 2:00 EST mid month. Saturn is best left until the pre-dawn to observe.

DEEP-SKY OBJECTS

Taurus is home to two of the closest and brightest open star clusters, the Hyades (see above) and the Pleiades, or M45 (RA 3h 47.0m, dec. +24° 07'). To the naked eye, the Pleiades shows six stars ranging from mag. +2.8 to +4.3, fitting within a 1° circle. Through binoculars M45 is breathtaking, easily revealing a couple of dozen stars out to 1° from the centre, the brightest members an obvious blue.

Another gem is the Crab Nebula or M1 (RA 5h 34.5m, dec. +22° 01'; pictured), the brightest supernova remnant in the sky and the most accessible to amateur astronomers. This slightly oval (4x5 arcminutes) hazy patch is easy to find, only 1° northwest of mag. +3.0 Zeta (ζ) Tauri. The larger your telescope, the more filaments and mottling you should be able to glimpse using averted vision.

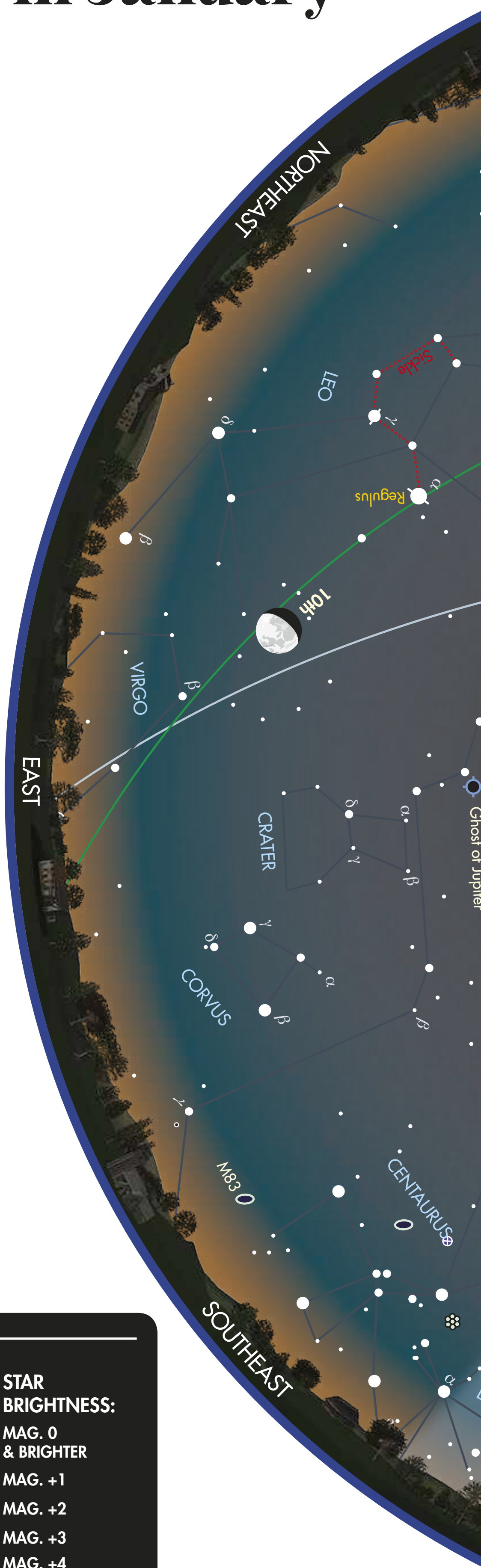
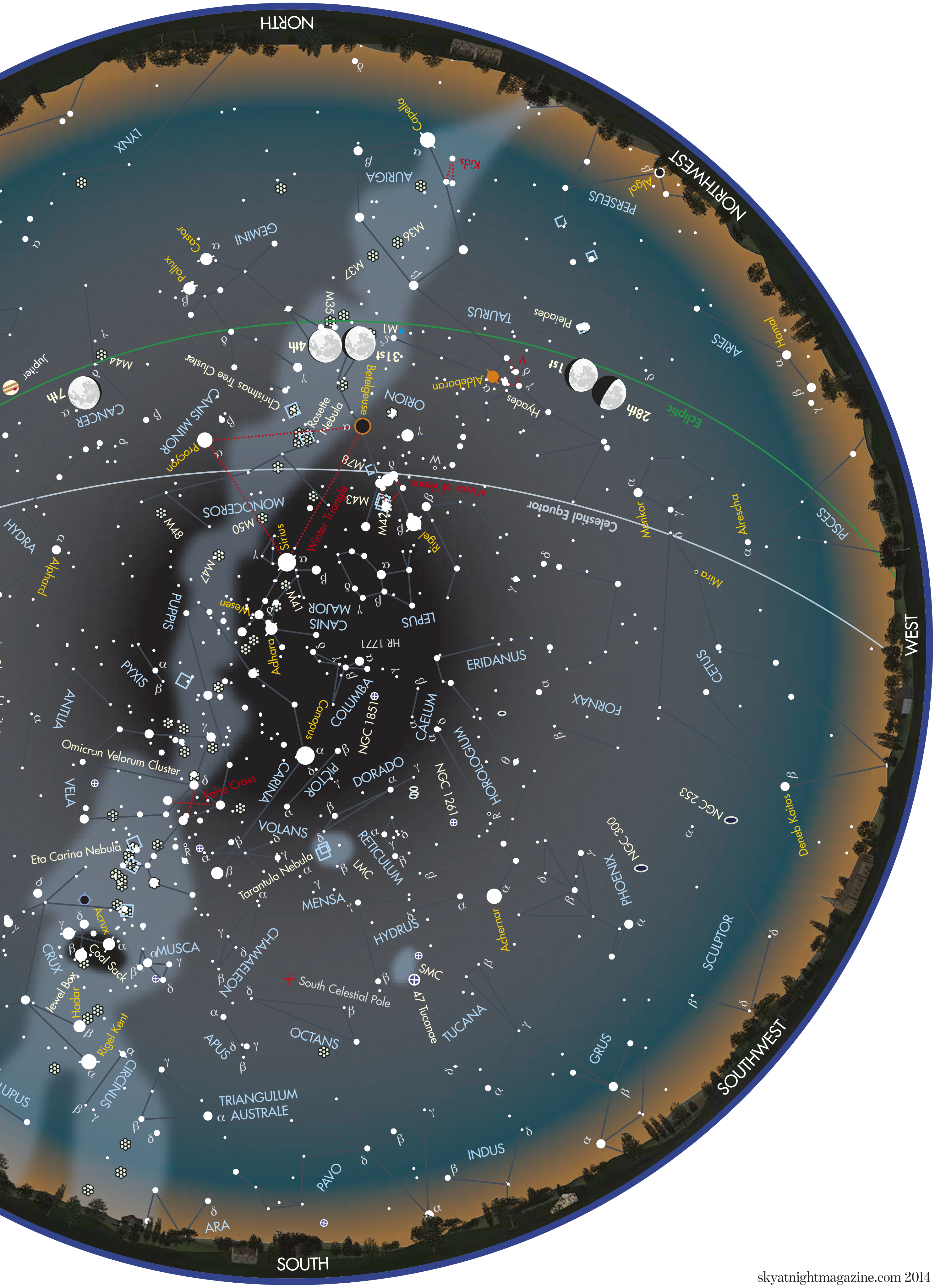


CHART KEY

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET

STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER

THINKSTOCK

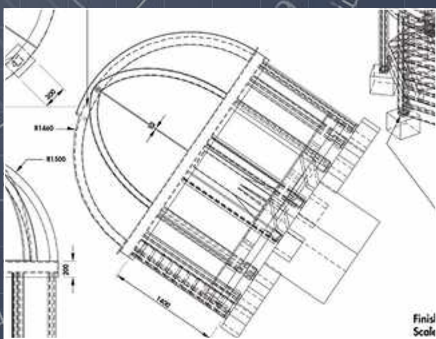

NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
LYNX
Capella
AURIGA
Kids
Algol
PERSEUS
GEMINI
Castor
Pollux
M36
M37
M35
M1
TAURUS
Pleiades
ARIES
Hamal
4th
31st
1st
28th
Jupiter
M44
7th
CANCER
Christmas Tree Cluster
Betelgeuse
Aldebaran
Hyades
Ecliptic
CANIS MINOR
Procyon
Rosette Nebula
ORION
M78
Mirror of Venus
Celestial Equator
Menkar
Alrescha
PISCES
MONOCEROS
M50
M43
M42
Rigel
Winter Triangle
Sirius
HYDRA
Alphard
M48
M47
M41
Mira
CANIS MAJOR
LEPUS
Wezen
PUPPIS
HR 1771
ERIDANUS
CETUS
Adhara
PYXIS
COLUMBA
NGC 1851
CAELUM
FORNAX
ANTLIA
Canopus
HOROLOGIUM
Omicron Velorum Cluster
VELA
False Cross
CARINA
PICTOR
DORADO
NGC 1261
NGC 253
Diphda
NGC 300
Deneb Kaitos
VOLANS
Eta Carina Nebula
RETICULUM
LMC
Tarantula Nebula
PHOENIX
MENSA
Acrux
CRUX
Coal Sack
MUSCA
HYDRUS
Achernar
SCULPTOR
CHAMAELEON
SMC
South Celestial Pole
47 Tucanae
TUCANA
Jewel Box
Hadar
Rigel Kent
APUS
OCTANS
CIRCINUS
GRUS
LUPUS
TRIANGULUM AUSTRALE
INDUS
PAVO
ARA

BBC Sky at Night MAGAZINE

BUILD YOUR OWN OBSERVATORY

BY MARK PARRISH

Steps, plans, diagrams and galleries: all you need to build your own home dome



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Be among the 20% of the UK's population to experience true darkness and the elite 2% that see the Milky Way. Crystal clear skies, protected Dark Skies and the Milky Way stretching from horizon to horizon.

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BUILD YOUR OWN **OBSERVATORY**

As I write this introduction, I am looking at my observatory out of the living room window and I have to say it is hard to imagine a time when it wasn't there. It really has taken the struggle out of my observing and made it simple, to such an extent that I sometimes wonder if I'm becoming a bit complacent!

When I feel the urge – and the sky obliges – I simply switch on the power, take the key from its hook, open up the dome and I can be observing within just a few minutes, sheltered from the breeze and nearby streetlights. All my kit is close to hand and, if the clouds roll in, I can be packed up and back in the warm in a matter of moments.

That was the plan from the outset, and the observatory has certainly lived up to expectations. I am pleased to have heard from several readers who have built their own based on these plans, after the four-part series was first published in 2009. I hope that this supplement will inspire many more – either following them closely or developing and adjusting the techniques to suit their own aspirations and situations.

A tour of 'The Dome' is always popular with visitors, and even though it has weathered a little and the accumulation of 'useful clutter' inside has increased, it continues to function very well indeed. I do need to be a bit more assertive with my hedge trimming and tree pruning this autumn, though – my window of sky has been gradually shrinking!

Mark Parrish, craftsman and amateur telescope maker

CONTENTS

PART 1 LAYING THE FOUNDATIONS

Pick the right site and establish the foundations of your home-built observatory

Carefully marking out the observatory now will prevent problems later on

You can't beat a night under the stars with your telescope, but this usually involves lugging heavy equipment outside and assembling it, by which time you may find that the clouds are rolling in. With a garden observatory at home, you simply open the roof and in a few minutes you're stargazing. When it's time to stop, just close up and head indoors.

There are many styles of home observatory. Commercially made glass-reinforced plastic domes are an instant – although expensive – solution, but home-built options also include apex-roofed sheds with roll-off or lift-off roofs. If space is tight you can make a small enclosure that rolls back on wheels. Every style has its merits and drawbacks, but the great thing about designing and building your own observatory is that you choose the best size, layout and appearance for your particular situation.

In this four-part guide we will follow the construction of a domed-roof observatory. This is ideal for a site with strong winds, local light pollution and limited space, because the dome shields the telescope and any observers within it.

In this first part, we're going to consider how to pick a location and how to cast the concrete foundations. On the following pages we'll cover creating a framework for the walls and floor; constructing the dome itself; and finally fitting out the interior.

"It's a good idea to check with your local planning authorities"

The construction methods and principles we describe can be used with other designs, and the materials and techniques will be familiar to anyone with DIY experience. So read on and begin dreaming of your own miniature Kitt Peak.

Location, location

Before starting, you need to carefully consider the siting of your observatory. Spend several nights with your telescope on a portable mount, trying different locations. There are a number of factors to consider, all influencing where you get the best views. Remember that for planetary and lunar observations a clear view of the southern sky is essential. Could small trees eventually grow and block your view? Do house lights cause a nuisance? Is the site secure? Make a note of the optimum position and decide how high the mount should be.

Once these practicalities are resolved, check that you have permission to build. With the aid of sketches or photos of similar projects, talk to your family – especially if a favourite flowerbed will require 'modification'! It's also a good idea to check with your local planning authorities. Temporary structures less than 3m tall are usually allowed, providing that they are not too close to buildings or beyond the boundaries set by building lines. An informal chat with the planning department may be all that is required. Inform your neighbours as well – a good relationship will help things run smoothly. If they feel involved, they will more readily

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understand future requests to trim bushes and turn off security lights.

Our design has eight concrete pads below the wall posts and a large block (almost 1m^3) for the central pier. Bolting the mount to this solid mass of concrete keeps it aligned and stops vibrations at the eyepiece when walking around on the floor above. Because the floor is raised, additional shuttering (wooden support) was used to provide a short column on which to fix the steel pier. Eight M12 threaded rods 1m long were cast into this column to provide reinforcement, and 50mm lengths were left sticking up to which the pier base was bolted.

Sawing and nailing together the shuttering, and mixing concrete, is hard but rewarding work. Neatness isn't vital, but ensure that each surface is level and smooth to avoid problems later on. We used 1.5m^3 of ballast and 12x 25kg bags of cement altogether, mixed in a ratio of about 6:1. While you are waiting for the concrete to harden, you can begin preparing the timber sections.

Once your foundations are laid, follow the steps on the next spread to find out how to construct the wooden framework for the walls and floor.

TOOLS AND MATERIALS

MARKING OUT TOOLS
A tape measure is essential, as is a spirit level and string.

MIXER AND BARROW
Hire a cement mixer and use a wheelbarrow to transport wet concrete.

PEGS
Make pegs from 1x2-inch timber.

SHUTTERING BOARD AND TOOLS
A handsaw, hammer, nails and a selection of plywood or chipboard pieces.

SPADE AND SHOVEL
A spade and a shovel for shifting ballast and concrete.

STEP-BY-STEP GUIDE

STEP 1
Carefully mark out the ground using wooden pegs, straight poles and string. Peg tops, which are used as a reference for the top of the concrete, should all be hammered down to the same level and checked with a spirit level rested on a long bar.

STEP 2
Dig the pad holes (400x400x400mm) and central pier hole (900x900x900mm). If you dig the holes carefully you may not need any shuttering, but offcuts of timber or plywood nailed together can be used to keep the edges neat.

STEP 3
Here we've used chipboard to make shuttering, which gives the concrete neat edges and sides. Make a frame to hold the eight 1m-long threaded rods in place while the concrete in the central pier base sets. Use a spirit level for accuracy.

STEP 4
A cement mixer (and plenty of help) makes mixing the concrete easier. Protect grass and plants from cement dust. Add enough water to make a 'dropping' consistency similar to thick porridge. Wash all your tools before the concrete on them sets.

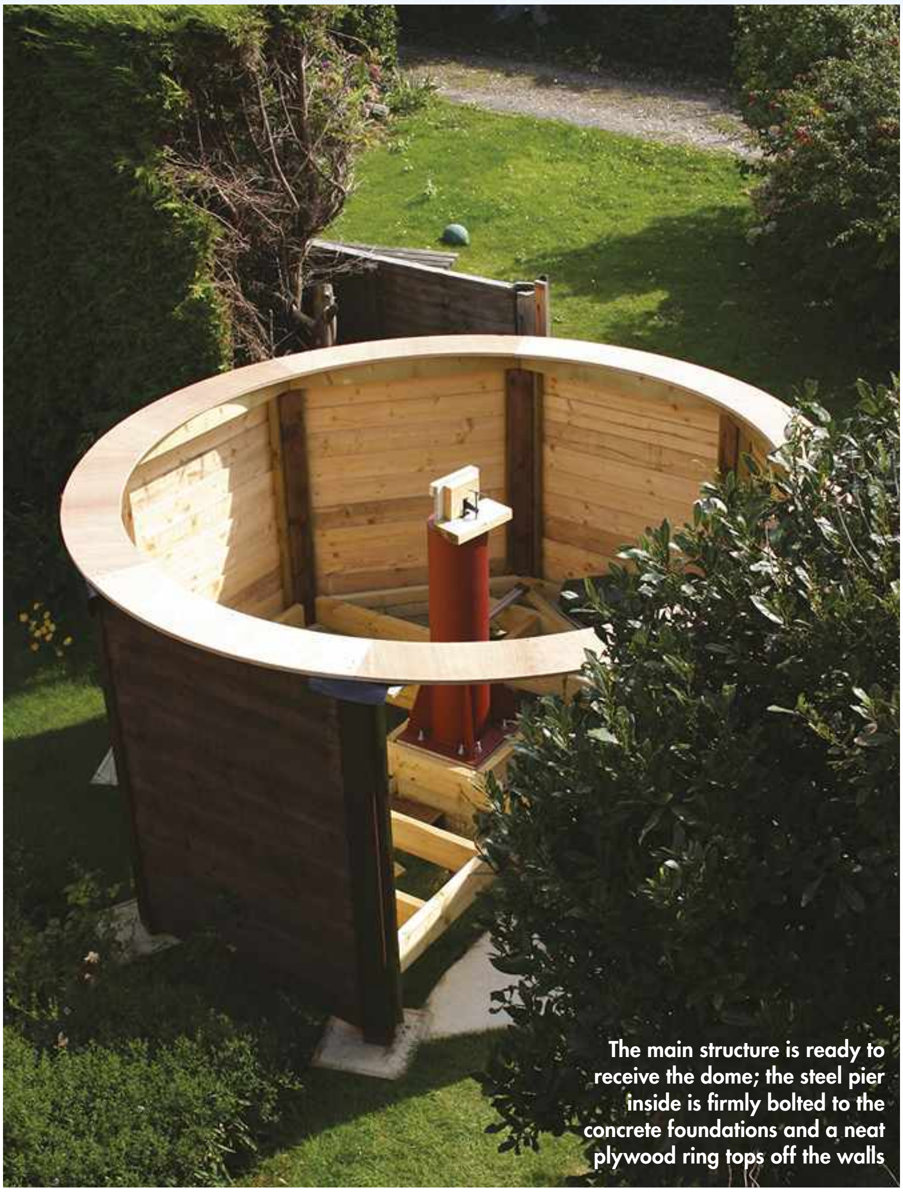
STEP 5
Pour in the mix and pat it down to remove air pockets. Top up to the correct level then use a trowel to smooth the surface. Make a square frame to form a lip on top of the pier base. This will help you align shuttering for the top part.

STEP 6
Once the concrete begins to set, fit your frame around the upper section of the pier and pour in the remaining concrete. The shuttering can be carefully removed after a couple of days, but don't chip any edges, which take much longer to go hard.

TURN THE PAGE FOR PART 2 ▶

PART 2 CONSTRUCTING THE WALLS

How to turn your stack of timber into the beginnings of a building



The main structure is ready to receive the dome; the steel pier inside is firmly bolted to the concrete foundations and a neat plywood ring tops off the walls

▲ A jig was built for the router to cut the eight curved sections for the plywood ring on top of the observatory walls

Once all the concrete work is complete, you can start work on the observatory's walls and floor. This doesn't involve any complicated joints, just careful cutting and fixing with screws and nails. You may need help to erect the posts, but once they are upright, construction is fairly straightforward.

The eight posts have wooden strips on either side, to which the wall cladding will be fixed. They also have hardwood blocks attached that hold the joist support beams, plus pads on the bottom. We used hardwood offcuts for these pads, but you could improvise with thick plastic or ceramic tiles – anything that separates the wood from the damp ground.

You should first loosely erect the structure and then make adjustments so that the posts are evenly spaced and upright. An offcut of wood, bolted to the central column, provides a useful reference point to take measurements from. Tap a nail into it and you can use a length of string to ensure all the posts are the same distance from the centre of your observatory.

If some of your concrete pads aren't quite level, you can add a little packing under the relevant posts. When you're happy with the alignment, screw all the parts tightly together. A powered screwdriver is a great help here.

Floor-less vibrations

When you come to the joists, the first to place are the long ones either side of the central column. Leave a gap of about 10mm between the concrete and the wood so that vibrations from walking on the floor aren't transmitted to the telescope.

We used 75mm woodscrews, screwed in at an angle of about 45° from either side, to fix the joists onto the supporting beams. Next, fix a joist at right angles to form the step. The remaining joists are placed at an equal spacing (about 400mm apart) until you reach the edges. Some angled cuts are needed at the edges or else the wall cladding may not fit properly.

In between the main joists, nail short sections of the same timber to brace the structure. Our joists were 50mm wide and 150mm deep, but if you want to calculate your own depth, use this formula as a guide: **depth in mm = [(span in mm ÷ 600) x 25] + 50**. We decided not to fix the floorboards to the joists until the dome was in place, as rainwater could damage them.

Next, cast a simple concrete floor under your step. Alternatives could be a gravel patch or a simple paving stone. This will help to prevent wear and will stop muddy footprints getting into the dome during wet weather.

For our cladding we used sawn and treated 'feathered edge' fencing boards. These are screwed into place with an overlap of about 30mm, starting close to ground level with the thin sides at the top. A smoother, but more expensive,

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option is interlocking tongue-and-groove board, and a cheaper option is plywood; the choice here is a personal one because the outward appearance will be quite different for each. A dark brown preservative paint was then applied to the outside. If you line the inside of the observatory with plywood or coated hardboard panels, it provides a smooth surface for putting up your sky charts and astrophotos.

Finally, cut the eight sections of the plywood ring that fits round the top of the wall posts. This ring provides a fixing surface for the dome wheels and also makes a great shelf for eyepieces and cups of tea. We made a jig (a frame to hold a piece of wood in position) that enabled us to cut the plywood sheet to the required radius using a router, but it could also be cut with a jigsaw.

At this stage you should also bolt the steel pier to the central concrete column. The top of the pier was used to hold our router on its jig to trim the ring to a perfect circle once the pieces were screwed to the post tops. With the ring in place on, don't forget to cover up your construction with plastic sheeting to protect it from rain while you prepare for the next phase.

TOOLS AND **MATERIALS**

POWER TOOLS
A circular saw, router or jigsaw for cutting the wood. You can hire these tools.

TIMBER
Eight 153x100x100mm treated fence posts, 150x50mm timber for the floor joists, 100x50mm timber for the joist beams, and a sheet of 18mm plywood.

WOOD PRESERVATIVE
Water-based fencing paint is available in many colours.

WOODWORKING TOOLS
A handsaw, plane, hammer and screwdriver, plus nails and screws.

STEP-BY-STEP GUIDE

STEP 1
Cut sections of timber for the eight posts, joist supports and top bracing. A circular saw will make short work of the angled cuts, but these can be done with a handsaw. All our timber is pre-treated, but freshly exposed cuts require preservative.

STEP 2
Screw together the sections for each post. Use galvanised coach bolts to hold the hardwood blocks that will support the floor and hardwood pads below the posts as they are more water resistant. Coat all the wood with preservative.

STEP 3
Assemble the posts and joist supports. Use one woodscrew for each joint at first, to allow small adjustments to be made. All posts must be upright and evenly spaced. You can still see the wood shuttering on the central column in this photo.

STEP 4
Cut the floor joists and fix them into place. Make sure there is a gap between the column and the joists to prevent vibrations. Short sections of joist between the main lengths stiffen up the structure. Note the gap on the top left for the step.

STEP 5
Nail the wall cladding boards between the posts. Start at ground level and work up, trimming the top board if necessary. Note the optional cast concrete floor inside the entrance to the observatory. The short post under the step provides support.

STEP 6
The steel pier is bolted to the column using the protruding threaded rods. A temporary wooden block clamped to the top of the pier (see image on page 6) can be used (with a string line) to help set out the posts and trim the ring sections on top of the walls.

TURN THE PAGE FOR PART 3 ▶

PART 3 BUILDING THE DOME

Now it's time to assemble the rolling roof that will protect your telescope

Two continuous rib sections form the shutter opening

The third part of our observatory project – building the hemispherical dome – is not as tricky as it sounds. The curved ribs are cut using a simple jig that you can make yourself, and because the dome is coated with a strong, glass-reinforced plastic (GRP) layer, you can get away with a few gaps.

It's important to build the dome on a level surface, so that it rolls around smoothly on its runner when fitted. Building ours, we supported it on a ring of level wooden pegs hammered into the lawn. A central peg with a string line is useful for checking that the shape is circular as work progresses.

Spend some valuable time making a jig to hold your router or jigsaw. We made a frame on which to rest the sheets of plywood and added a long swinging arm. Our router was clamped at various positions along the arm to cut different sections.

The main ring is made from two layers of 12mm plywood, and each layer is made from eight segments. Glue and screw the layers together with the joints staggered to form a rigid, 24mm thick ring. A thin plywood skirt was glued and nailed to the outside edge. Because the ring was supported on raised pegs, the skirt didn't have to take any weight during the dome's construction.

Next, two continuous rib sections were cut to form the shutter opening. These were reinforced with a second layer of plywood. Around the opening, this second layer protrudes to form a lip that keeps the rain out. Two similar ribs were then added at 90° to the shutter ribs. We used pre-drilled steel brackets and screws to fix them at the top and bottom. Temporary wooden spacers inserted between the shutter ribs kept the opening parallel.

The four remaining ribs were cut from one layer of plywood and fixed at 45° to the shutter ribs using butt hinges. Because of the geometry, the hinges don't move, and using them means you don't need to make a tricky joint!

Putting it all together

Adding the hardboard skin is easier with an extra pair of hands. We held a whole sheet in place over the relevant ribs and traced the shape from inside with a pencil. Then we cut out each

▲ **The lifting-on party: a great opportunity to show your creation to friends and neighbours (and get them to do the hard work!)**

panel using a jigsaw and held it up to the ribs to check the shape, before gluing and nailing them in place.

A similar technique is used to make the two sections that form the shutter. Tubes of gap-filling adhesive (available from builders' merchants) are excellent for this. Once all the panels were fixed, a generous squirt of glue was used to seal and reinforce all the joints and any rough edges were sanded down. Rough-sanding the whole surface helps the GRP resin to make a good bond.

Adding the GRP layer is fun, but messy and sticky. Do read the manufacturer's safety guidance, work in a ventilated

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space – preferably outside – and certainly avoid contact with the skin. The process involves applying resin to the whole surface, sticking strips of GRP matting over each joint to make them smoother and stronger, then sticking a layer of GRP matting over the whole surface of each panel, working it into the resin with a roller.

Lastly, we applied a layer of grey-coloured gel coat, which seals the surface and provides the required colour. When this is set, there may be some trimming and sanding to do, but the dome will require no further finishing and becomes rigid, waterproof and strong.

Our dome runs on eight pairs of rubber-tyred wheels, eight supporting the dome and eight facing outwards to guide it round. Once all the wheels are fixed to the wall ring above each post, enlist the help of as many friends as you can muster to lift the dome onto the structure. We found it easiest to lift and manoeuvre the dome when it was supported on two aluminium ladders. One team lifts it from outside, while those inside the observatory take the weight while the ladders are slid away, before lowering it onto the wheels.

TOOLS AND MATERIALS

GLASS-REINFORCED PLASTIC (GRP)
We used chopped strand matting to cover the dome and reinforced the joints with chopped strand tape. Resin bonds the matting together.

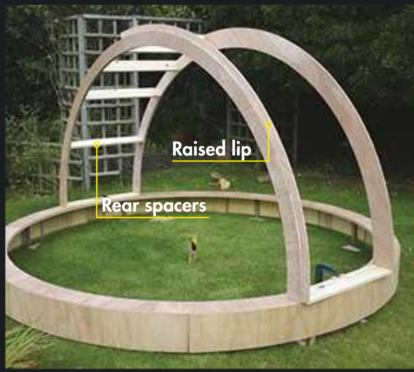
GRP TOOLS/ EQUIPMENT
Mixing buckets, old rollers and brushes, acetone, safety gloves, overalls.

POWER TOOLS
A router or jigsaw to cut the curved plywood parts of the ring.

TIMBER
12mm plywood for the ribs and main ring. Thin (2mm approx) plywood for the skirt and shutter skin. Hardboard for the main dome panels.

STEP-BY-STEP GUIDE

STEP 1
Build a double-thickness plywood ring, supported on wooden pegs. The joints are staggered to improve the strength. Bend thin plywood around the edge to form the skirt. Run a length of string from a central peg to check the shape is circular.



STEP 2
The two main ribs are screwed to the main ring using metal brackets. A raised lip around the shutter opening is formed by an inner layer of plywood. The rear spacers will stay in place, but temporary spacers will help to keep the opening parallel.

STEP 3
Three further ribs are fixed on each side of the main ribs. We used normal hinges to join them at the top and bottom. Cut the ribs a little long, then trim them to suit the position. A stepladder comes in handy for reaching the top.

STEP 4
Cut out the hardboard panels and fix them to the ribs with nails and gap-filling adhesive. The panels will form curved 'facets' rather than a perfect hemisphere. Sand down any ridges then use more adhesive to reinforce joints and fill gaps.

STEP 5
Roughen the surface of the hardboard, then coat with resin, chopped strand matting and more resin. Don't mix too much resin at a time or it will set in the bucket. Work it in well using rollers, and complete the job with a coloured gel coat layer.

STEP 6
Eight heavy-duty 100mm fixed casters with rubber tyres above the posts take the weight, while eight smaller horizontal wheels, held by steel brackets, guide the dome round by touching the skirt. Once these are in place, the dome can be lifted on.

TURN THE PAGE FOR PART 4 ▶

PART 4 FINISHING TOUCHES

You're almost ready to start exploring the night sky from your new observatory

The completed observatory ready for use; the fully opened shutter provides clear views of the sky

▲ Inside is a perfectly aligned telescope ready for use at any time; a dream come true

Now that your project looks like a completed observatory, you'll be anxious to get inside and start observing. However, there are still a few final details to get sorted. Here, we'll cover the finishing touches that will help you to set up your observatory for maximum satisfaction.

First comes the shutter, which is made in two sections. The main section rolls back beyond the opening, allowing a clear view overhead. In order to see down to the horizon, the lower section can be lifted out. The shutter's main section is fitted with small, fixed caster wheels that run directly on the dome's surface. Additional wheels, mounted sideways between the inside edge and the lip around the opening, guide the shutter while closing. You could open and close it with a long pole, but for a touch of sophistication we installed a pair of pulleys and a strong cord to operate the shutter. A cleat is used to tie off the cord and hold the shutter closed.

Batten down the hatches

Although the dome and shutter are heavy, it is important to provide methods to keep them in place during strong winds. We used sliding bolts to secure the shutter and four long, bent strip hinges that flap down over the wall ring to stop the dome lifting.

A step is desirable if your floor is high. We opted to build a step to bridge the distance between the ground and the floor, and also fitted a useful doormat (as you can see in the open doorway of the observatory on the left). Fortunately, we have never fallen down the step. But if you sense this might be hazardous in the dark, you could make a removable floor panel to cover the gap. The door is built from a 75x50mm timber frame with cladding to match the walls. Strong hinges and a good-quality lock are recommended for security and durability.

A plush interior

Power and lighting requirements are a personal choice; many observers use portable batteries for powering mounts and red torches for lighting. However, we opted for mains power and chose to install two dimmable red lights, two white lights for maintenance work and a pair of mains sockets so we could use a computer. The power comes from the house via an armoured cable running in a deep trench and is protected by a residual current device (RCD) circuit breaker. All the electrical work should be carried out by a registered electrician. You might also consider installing network cabling so you can use the internet in your observatory.

Once the services were installed, we painted the inside of our dome with a

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wood preservative, followed by a matt black emulsion. The interior woodwork was given a gloss varnish. Then we laid a tongue-and-groove wooden floor, which is nailed to the joists. If you expect to lift your floor to make future changes, straight-sided boards fixed with screws may be preferable. We lined our walls with thin (3mm) panels of MDF. You don't need to insulate the walls, but lining does make it easier to pin up charts and photos. A pale wall colour helps you find your way around when the lights are dimmed.

Finally we added some useful furniture. Space dictates what is possible, but a small desk is good for your laptop, eyepieces and charts, and a stool is welcome for resting your legs. If you have a tall mount you may also wish to make some moveable steps to reach the eyepiece. Most of the furniture spends its time on the northern side of our dome, but we recommend not fixing anything permanently as you will inevitably want to move it at some point.

Hopefully you'll soon be observing from your very own dome. You may opt for a different design, but many of the issues will be similar. If you have made the effort, your enjoyment of the night sky will be even more satisfying.

TOOLS AND MATERIALS

DECORATING EQUIPMENT
Rollers and brushes, black emulsion paint and varnish; gloves and overalls.

ELECTRICS
A pair of mains outlets, dimmable red lights, white lights, buried armoured cable and a protective RCD device, telephone and network cable.

TIMBER
18mm floorboards (either tongue-and-grooved or plain) thin plywood or MDF (3-6mm).

TOOLS
Hand tools for cutting and fixing the floorboards.

STEP-BY-STEP GUIDE

STEP 1
The shutter panels overlap the opening like a lid. They could be lifted on and off, but small casters fitted to the edges run smoothly over the curved surface of the dome so the main section can simply roll back. We painted the inside matt black.

STEP 2
Fit a pair of pulleys near to the top of the shutter opening. A strong nylon cord (4-6mm thick) is used to open and close the shutter. A cleat fixed to the lower edge enables you to tie the cord off, securing the panel when closed. We also fitted sliding bolts.

STEP 3
As well as a good quality door lock and bolts, we used long bent hinges to make the observatory secure. These flap down from the dome and prevent it lifting or being lifted. To rotate the dome, simply flip them back up.

STEP 4
Lights, power sockets and communications cables will enhance your experience. We selected tough bulkhead lights to resist knocks. Some have dimmable red bulbs to preserve night vision. A qualified electrician should carry out this work.

STEP 5
Once all the painting and wiring has been done you can fit the wooden floor. Nailing the boards in place is fun and a sign that you are nearing the end of the job. If you want, you can line the walls with thin wooden panels.

STEP 6
Small items of furniture and equipment (depending on requirements) can now be installed. Make sure you leave enough room to operate your telescope. It is wise not to permanently fix anything, as you will inevitably need to move it around.

TURN THE PAGE FOR MORE PICTURES ▶

▲ The observatory's roof shutter is made of two parts: the upper one rolls back, while the lower one lifts out

► Once the observatory is fully constructed and installed, you'll be able to begin your stargazing sessions within a matter of minutes

▼ The pier is bolted into a block of concrete separated from the floor, meaning you can walk around it without creating vibrations

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COST ESTIMATES FOR OBSERVATORY CONSTRUCTION

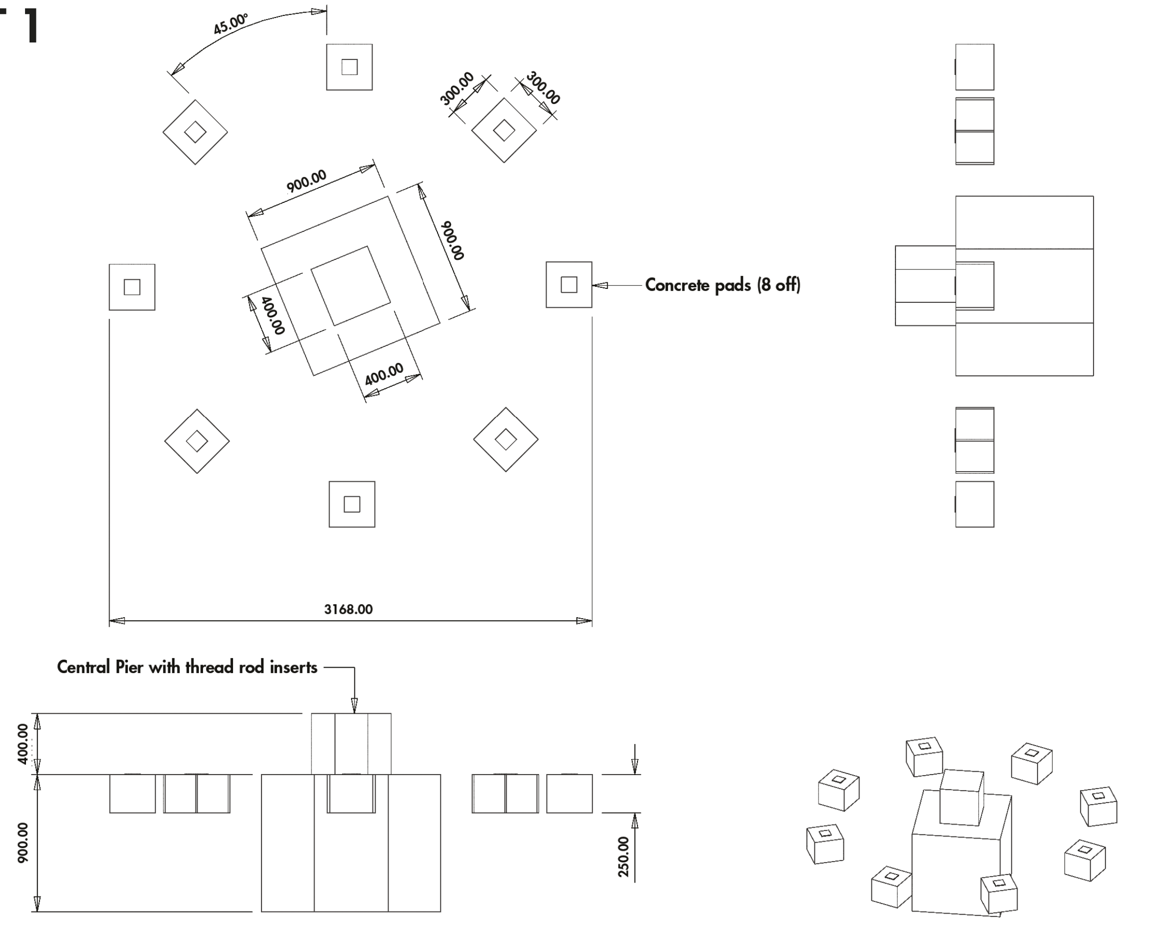
ITEM	DETAILS	AMOUNT	UNIT	COST/ UNIT	COST
CEMENT	25KG BAGS	12	BAGS	£5.90	£70.80
BALLAST	1M³ BULK BAGS	1.5	BAGS	£40	£60
WALL POSTS	100x100 TREATED SOFTWOOD	12	METRES	£5	£60
CLADDING BATTENS	50x50 TREATED SOFTWOOD	24	METRES	£1.50	£36
JOIST SUPPORT BEAMS	100x50 TREATED SOFTWOOD	10	METRES	£2.30	£23
TOP OF WALL STRIPS	100x25 TREATED SOFTWOOD	10	METRES	£1.30	£13
HARDWOOD FOR BLOCKS	100x30 HARDWOOD	1.8	METRES	£2	£3.60
FLOOR JOISTS	150x50 TREATED SOFTWOOD	30	METRES	£2	£60
FLOOR BOARDS	140x18 TONGUE & GROOVE	50	METRES	£1.20	£60
WALL CLADDING	150x15 FEATHERED-EDGE TREATED	110	METRES	£0.65	£71.50
WALL RING	2,440x1,220 18MM PLYWOOD	1.5	SHEETS	£33	£49.50
DOME RING	2,440x1,220 12MM PLYWOOD	3	SHEETS	£25	£75
DOME SKIRT	2,440x1,220 3MM PLYWOOD	1	SHEET	£12	£12
DOME RIBS	2,440x1,220 12MM PLYWOOD	4	SHEETS	£25	£100
DOME CLADDING	2,440x1,220 3.6MM HARDBOARD	7	SHEETS	£6.60	£46.20
SHUTTER CLADDING	2,440x1,220 3.6MM PLYWOOD	1	SHEET	£12	£12
RESIN	3 LAYERS, EACH AROUND 7.2KG	1	20KG DRUM	£51	£51
CHOPPED STRAND MAT	16M² (10M ROLLS) OF 450GM	2	ROLLS	£16	£32
GEL COAT	1 LAYER OF 3.5KG	1	5KG DRUM	£28	£28
CATALYST	500G ADDED TO RESIN & GEL COAT	1	1KG BOTTLE	£9.50	£9.50
CASTERS	100MM FIXED CASTERS	8	CASTERS	£5	£40
SKIRT CASTERS	50MM FIXED CASTERS	8	CASTERS	£4	£32
SHUTTER CASTERS	30MM FIXED CASTERS	8	CASTERS	£4	£32
					TOTAL: £977.10

ADD COST OF SUNDRIES SUCH AS SCREWS, NAILS, PAINT, WOODSTAIN AND ELECTRICS DEPENDING ON REQUIREMENTS

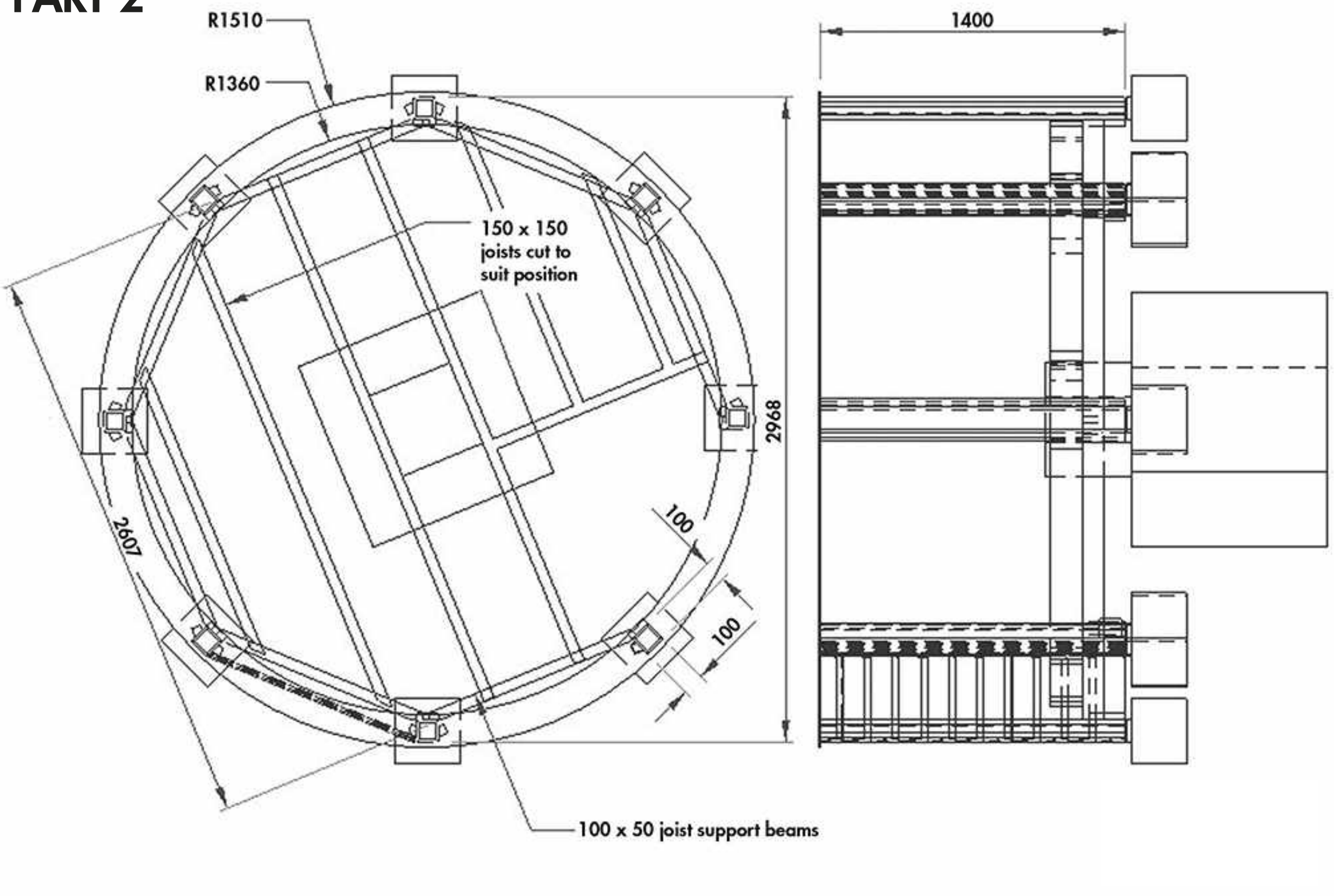
TURN THE PAGE FOR CAD PLANS ▶

CAD PLANS

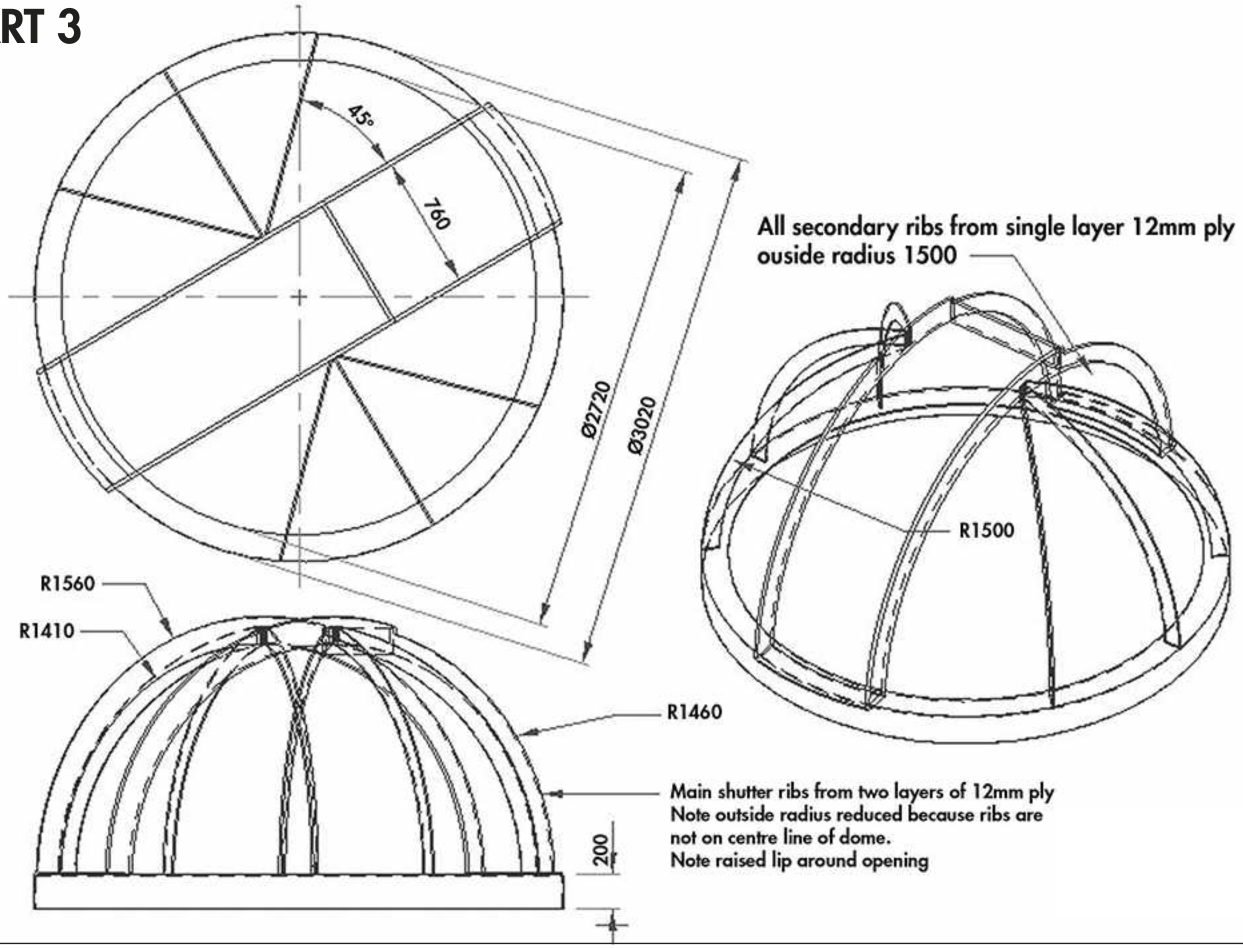
PART 1



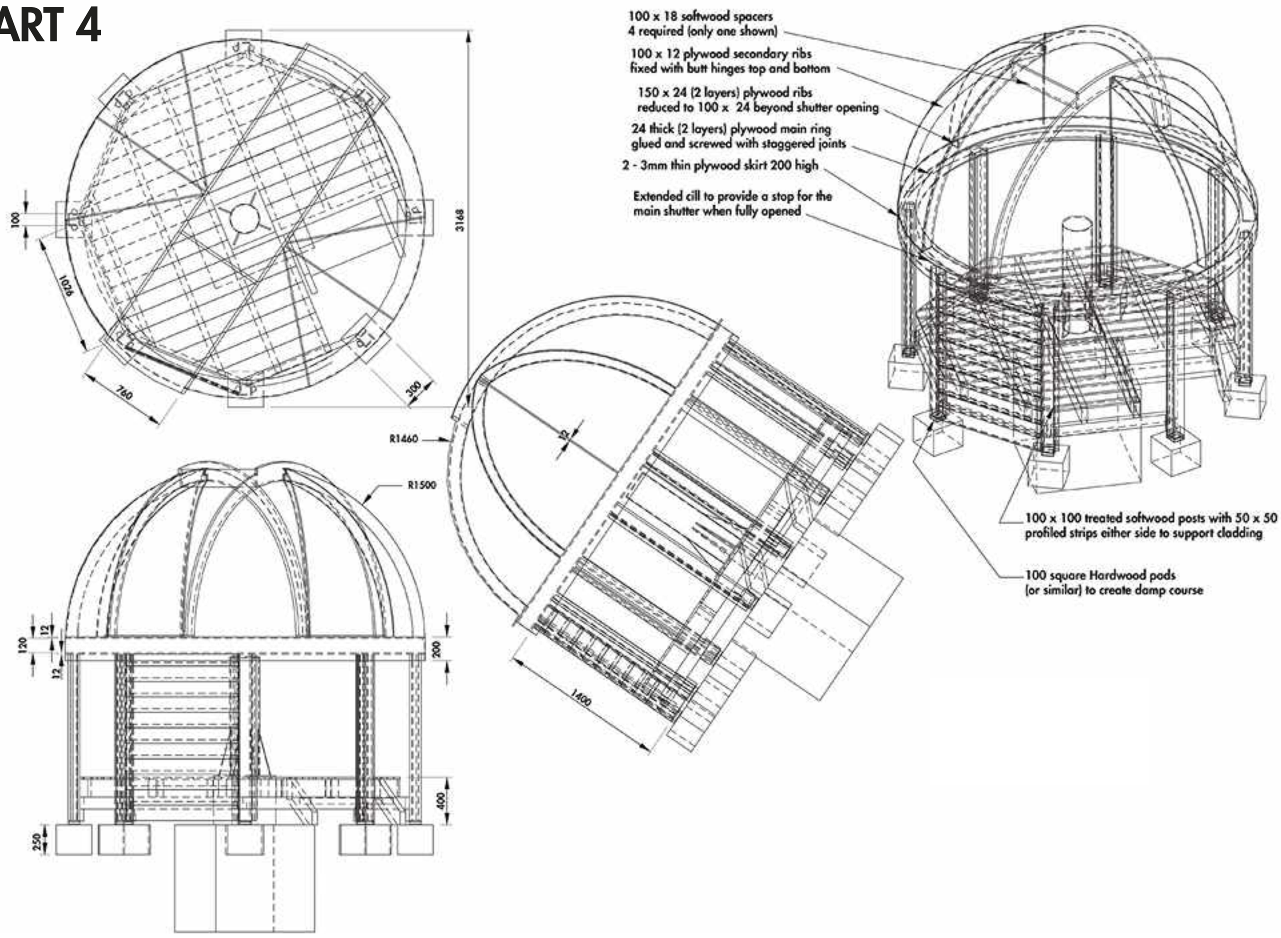
PART 2



PART 3


45°
760
Ø2720
Ø3020
All secondary ribs from single layer 12mm ply
ouside radius 1500
R1500
R1560
R1410
R1460
Main shutter ribs from two layers of 12mm ply
Note outside radius reduced because ribs are
not on centre line of dome.
Note raised lip around opening
200

PART 4


100 x 18 softwood spacers
4 required (only one shown)
100 x 12 plywood secondary ribs
fixed with butt hinges top and bottom
150 x 24 (2 layers) plywood ribs
reduced to 100 x 24 beyond shutter opening
24 thick (2 layers) plywood main ring
glued and screwed with staggered joints
2 - 3mm thin plywood skirt 200 high
Extended cill to provide a stop for the
main shutter when fully opened
100
1026
760
200
3168
R1460
R1500
1400
120
12
12
200
400
250
100 x 100 treated softwood posts with 50 x 50
profiled strips either side to support cladding
100 square Hardwood pads
(or similar) to create damp course

UK Retailer Guide

Find the right one for you: buy your telescope from a specialist retailer

It is quite easy to become daunted by the vast array of equipment that is available to today's amateur astronomers. Different makes, different models, different sizes and optical arrangements – if you're new to the hobby, how do you make sense of all these details and find the telescope that will show you the Universe?

The answer lies in buying from a specialist retailer – somewhere that really knows what they're talking about. Like the retailers in this guide, they'll have the practical knowledge that will guide you towards the scope that won't end up gathering dust in a cupboard.

Today there are over 1,000 models of telescope to choose from – refractors and reflectors, Dobsonians and Newtonians, Schmidt- and Maksutov-Cassegrains. And just as important as the telescope is the mount it sits on; but do you go for equatorial or altazimuth, manual or Go-To? And what about accessories like eyepieces and finderscopes?

That's certainly a lot to consider before making a decision, but a specialist retailer will help you make that decision, taking important considerations like portability, construction and price into account.

So if you need friendly, face-to-face advice and excellent aftersales service, free from biased opinions, specialist telescope retailers are the place to go for a helping hand through the technical literature and tables of figures. They'll help you find a scope that combines quality and convenience at a price that's right.

TELESCOPE HOUSE

Founded in 1785, Telescope House has been responsible for supplying many well-known Astronomers with telescopes and equipment. The late Sir Patrick Moore bought the majority of his telescopes from the company, including his very first instrument. With a friendly showroom in Surrey, a number one ranked retail website and a service centre with fully qualified staff, the company offers equipment from manufacturers such as Meade, Revelation, Coronado, Bresser, Skywatcher, Orion USA, TeleVue, Vixen and Explore Scientific. Whether it's advice on your first telescope, to setting up advanced Astrophotography systems, the staff at Telescope House have a wealth of experience and instant access to the right stock to back it up.

Telescope House
Broadhurst Clarkson & Fuller Ltd. - Established 1785

☎ **01342 837610**
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sales@telescopehouse.com

TRING ASTRONOMY CENTRE

At Tring Astronomy Centre we know that choosing the right equipment can be a minefield, but we strongly believe that seeing telescopes in the flesh and talking to an expert in a relaxed environment can really help. That's why we have a coffee machine, a fully stocked bicuit barrel, and 45+ telescopes on display. As well as representing leading brands such as Celestron, Sky-Watcher, Baader Planetarium, Altair Astro, Vixen, Opticron, AstroTrac, iOptron, Lunt, Starlight Instruments, ZW Optical and many more we also offer a hire service so you can even try before you buy! So what are you waiting for? Visit or contact Tring Astronomy Centre and lets talk Astronomy!

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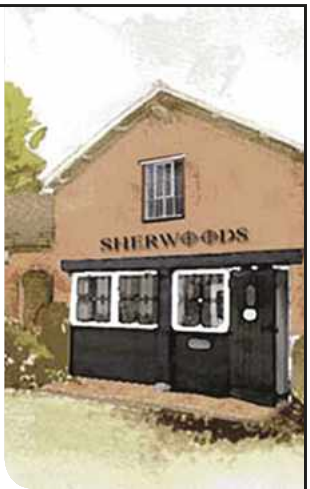

Established for over 60 years, we at Sherwoods are one of the Midlands leading suppliers of astronomical telescopes, binoculars and accessories. Through our website and showroom we are able to supply optics from some of the world's leading optical manufacturers including Celestron, Skywatcher and Meade at some of the lowest prices in the UK. We offer a full mail-order service including next day delivery on many items held in stock.

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The Widescreen Centre since 1971

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Green Witch is one of the UK's leading suppliers of telescopes, binoculars and accessories for astronomy. Founded by former members of the Royal Greenwich Observatory in 1998, Green Witch is dedicated to helping you choose and use the equipment that is right for you.

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